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PHYSCIAL SCIENCES AND TECHNOLOGY
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CONTENTS (Continued)

GEOPHYSICS, ASTRONOMY AND SPACE

VARIED AND IMPORTANT ROLE OF SATELLITES

Moscow KOSMOS-ZEMLE in Russian 1976 pp 13-15, 37-40, 76-89 and 97-182

[Selections from the book "Kosmos-Zemle" by M. I. Shtern, USSR Academy of Sciences, Series "Problems of Science and Technical Progress, "Izdatel'stvo Nauka]

/pp 13-15/

[Text] Laboratory in Space

The third Soviet satellite in the full sense of the word was an automatic scientific laboratory in space. According to its technical data, and the number of experiments conducted it exceeded its predecessors by a great deal. Its weight was 1,327 kg, including the weight of the scientific and measuring apparatus together with the power sources--968 kg.

The designing of the satellite took into consideration a number of specific requirements associated with the conducting on it of different scientific experiments and the placement of a large quantity of scientific and measuring apparatus. The possibility of reciprocal influence of individual scientific instruments required the thorough study of layout of the scientific apparatus.

The main portion of instruments for the scientific studies together with the power sources was placed within the satellite on an instrument frame located in its anterior portion. The placement of sensitive elements (gages) of the apparatus was determined by their purpose. Thus, the magnetometer was placed in the anterior section of the satellite, in order to remove it the maximum distance from the remaining apparatus. The cosmic ray meters were installed within the satellite. All the other gages were placed outside the hermetically-sealed housing. Thus, the photomultipliers that served to record corpuscular solar radiation were fastened on the anterior section of the housing. One magnetic and two ionization manometers that measured pressure in the upper layers of the atmosphere were installed in cylindrical cases welded into the shell again of the anterior portion of the satellite. The remaining apparatus was placed near them.

A stable temperature within the satellite was guaranteed by a system of thermoregulation which was considerably perfected in comparison to that used on the first satellites. The temperature was regulated by changing the forced circulation of gaseous nitrogen, as well as by changing the coefficient of natural radiation of its surface. For this, adjustable louvers consisting of 16 individual sections were installed on the lateral surface of the satellite. They were opened and closed by electric drives controlled by the apparatus in the thermoregulation system.

The use of solar batteries as a power source made it possible to obtain scientific information for a long time. The solar semiconductor battery was arranged in the form of individual sections on the surface of the housing. Four small sections were installed on the anterior bottom, four on the lateral surface, and one on the rear bottom. Such placement of the sections of the solar battery guaranteed its normal operation regardless of the orientation of the satellite in relation to the sun.

The multiple-channel radiotelemetric system of the third satellite differed in its high resolution. It could transmit to earth a large volume of information on the results of the scientific measurements.

To record high energy particles a luminescent meter was used consisting of a crystal of sodium iodide and a photomultiplier with a photo cathode.

The measurements results showed that in all cases without exception when the satellite entered a band of latitudes 55-65° both in the Northern and in the Southern Hemisphere a sharp increase was observed in the braking x-ray radiation, governed by the bombardment of the housing with electrons with energy on the order of 100 keV. It was also established that the radiation intensity increases with altitude. Both of these things were a consequence of the entrance of satellite into a zone of intensive radiation which soon received the name external zone of the radiation belt.

With the help of the photomultipliers designed to record the corpuscular solar radiation for the first time electrons were found directly with energy on the order 10 keV. A stream of these electrons was recorded at altitude from 470 to 1,880 km. Their intensity during the day was greater than at night, whereby it continuously changed with an increase in altitude and geomagnetic latitude. Since the position (orientation) of the satellite was known, then the direction of movement of the particles linked to the streams of electrons was successfully determined. It was found that they, as a rule, move perpendicular to the direction of the magnetic force line. Their velocity of movement exceeded a great deal the velocity of solar corpuscles, measured from observation of the aurora borealis.

Determination of the density of the upper atmosphere this time was made by observing the change in the parameter of the satellite orbit due to the braking and recording of pressure with the help of ionization and magnetic manometers.

A study of the parameters of the ionosphere was also made by different methods: observation of the spread of radio waves emitted by the powerful radio transmitter of the satellite, and with the help of the apparatus installed on it, so-called ion traps for the direct measurement of the concentration of positive ions along the satellite orbit. In addition, with the help of a radiofrequency mass spectrometer the composition of the positive ions was studied.

In order to measure the magnetic earth field at great altitudes a self-orienting magnetometer was installed that measured the complete intensity of the magnetic field at the altitude of the satellite's orbit.

On the third satellite the intensity of the primary cosmic rays was also recorded, and experiments were set up to determine the quantity of heavy nuclei in space radiation. Several gages recorded impacts of micrometeor particles.

The launching of the third artificial satellite that existed over 2 years and made over 10,000 revolutions around the earth permitted the Soviet scientists to conduct studies on all points of the corresponding section of the program of International Geophysical Year.

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Chapter 3 Object of Studies--the Moon

Space Laboratory

The closest celestial body to us, the only natural satellite of Earth, the moon long before the onset of the era of spaceflights was considered the most studied body in the solar system after our planet. In the most advanced telescopes one could distinguish on the lunar surface details with cross dimension of 1 km and even less. With the help of photometers and spectrographs the smallest nuances in its reflecting ability (albedo), color and much more were recorded. When after the Soviet automatic station "Luna-1" dozens of other spacecraft rushed to the moon the possibilities of studying it grew remarkably.

The moon with its craters and ring formations, mountain crests, "seas," and "bays" has essentially become a giant scientific laboratory.

Why is man drawn towards the moon? What explains the interest of scientists in our age-long satellite?

In answering such questions one often refers to man's striving to know his surrounding world. This is undisputably so. But in the actual striving for knowledge there lies an objective necessity for the further investigation of laws of nature and the use of them for the good of people. The guessing of secrets which the world of stars and planets hides will help to solve many, seemingly, purely terrestrial problems.

It is difficult to imagine life of modern man, the technology of today without the extensive use of minerals. Very great resources are expended for their prospecting. Exploration of new fields will become more effective if we have a better recognition of the organization of our planet. First of all it is necessary to obtain detailed data on the composition and structure of the deep interior of the earth, as well as information on the early stages of existence of the earth. However paradoxical, the answer to the question of how the earth is organized can be obtained as a result of studying the moon.

According to modern ideas, the moon, apparently, is a residue of solid preplanetary bodies, that were not encompassed by Earth in the process of its formation. Throughout its history the moon has been exposed to smaller geological changes than Earth, Mars and Venus. The processes of evolution left many traces on the lunar surface--craters of different sizes. Some scientists are prone to believing that in the majority of cases the craters were formed as results of impacts of meteorites on the lunar surface. One can hope that on the moon a considerable number of traces of evolution are preserved that reflect the early history of the solar system. From this viewpoint the moon is even of greater importance for studies than the planets.

Thus, study of the moon is inseparably linked to the problems of investigating Earth, its history and evolution, structure and composition of the interior, chemical and geological processes occurring in it.

What, for example, can an analysis of samples of lunar rocks sent to Earth provide? After determining in them the concentration of different radioactive elements and products of their breakdown the specialists establish when they were formed. This makes it possible to reveal supplies of latent radioactive energy in the depths of the moon. A total chemical analysis of the samples and data on the content in them of a number of scattered elements show which processes resulted in the formation of this substance, was it in a liquid, melted form or did it remain solid, crystalline. Special studies indicate which temperatures and pressures acted on the substance and what nature these factors had. Analysis of the lunar substance will help to open slightly the curtain over the early stages of planetary formation.

The far side of the moon also interested the scientists, for even the smallest differences in the structure of the visible and far hemispheres of the moon make it possible to understand the nature of the final stage in the braking of this celestial body--"the special point," when as a consequence of the tidal friction elicited by Earth the period of axial rotation of the moon became equal to the period of its rotation around Earth.

The moon opens enormous perspectives before astronomers.

On the moon where there is no atmosphere the entire range of electromagnetic radiation "is open" and accessible to direct observation and investigation. The results obtained here make it possible to judge the physical conditions, content of hydrogen and temperature at different points in the solar corona, and the chromosphere, the physical processes in the interplanetary medium, as well as in the ionosphere and atmosphere of Earth.

On a lunar observatory one can make a spectroscopic determination of the chemical composition of the planets in the entire range of the spectrum, in order to fix lines of gases and elements that are inaccessible to observation from Earth.

The moon is an ideal place to study the primary cosmic rays all the way to energies in the billions of billions of electron-volts. Such a possibility for studying high energy particles will permit scientists to penetrate deeper into the secrets of the structure of matter, and more successfully solve the problem of controlling thermonuclear processes. Physicists will obtain on the moon the most enormous laboratory with an ideal vacuum, and low temperatures.

As the artificial satellites have shown a considerable number of terrestrial problems can be solved only in space. Being many thousands of kilometers from the surface of the earth the instruments already have discovered in the seas and on dry land certain resources that are hidden from the observers located on Earth. From the moon one can observe the earth objects in size up to several tens of meters--hundreds of times smaller than those which one can see on the moon from Earth by using the same instruments. This is explained by the fact that the atmosphere of Earth that is dusty and in continuous motion is in direct proximity to its surface.

Finally, without breaking away from the real potentialities of science, and only slightly entering into the realm of fantasy one can raise the question: Has the time not come when people, having spent some important minerals in the earth's depths and having found them on the moon will consider it expedient to deliver these minerals to Earth? It is true that apparently it will be inexpedient to transport them from there in their natural form. But the possibility is not excluded of converting the mineral raw materials of celestial bodies into types of matter and energy convenient for transporting.

As Academician C. P. Korolev noted, organization on the moon of a permanent scientific station, and subsequently an industrial facility will permit the use of untouched and as yet unknown resources of this great celestial body close to us for science and the national economy.

We note that the volume and diversity of scientific information about the moon which science today possesses thanks to space research are determined first of all by the potentialities of the scientific apparatus installed aboard the space stations. And these potentialities, in turn, are governed by the weight and overall dimension limitations, energy resources, length of existence of the stations, peculiarities of their movement along the trajectory, and the nature of the information transmission. The tasks fulfilled with the help of space stations can be very diverse. The studies conducted by them mutually supplement each other, and enrich our knowledge about the moon. During the elapsed years astronautics has achieved outstanding successes in this direction.

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Orbital Scientific Station "Salyut"

The next stage in Soviet space research was the creation and launching into orbit of the station "Salyut"--a multiple-purpose orbital scientific station capable of solving a broad range of tasks in the near-earth outer space. The creation of the station and its preparation for launching to a great extent was promoted by the experience of developing and testing the manned spacecrafts in the series "Soyuz."

During the flight of the long-term orbital scientific station "Salyut" two main problems remained to be solved: study of the possibility of man's lengthy stay in space, and the conducting of a broad program of scientific experiments.

A large program of medical and biological experiments with the participation of the crew members of the station was envisaged to solve the first of these problems. A set of measures was developed to guarantee the comprehensive physical training of the cosmonauts in space, since the physical load makes it possible to a certain degree to compensate for the absence of gravitational forces when man spends a long time in weightlessness, and creates the conditions for accelerated readaptation of the organism after return to the earth.

In order to solve the second problem it was necessary to place in the modules of the station a large number of scientific instruments whose total weight exceeded 1,200 kg.

In the planning of the station it was also kept in mind that the fulfillment of a saturated program of scientific and technical experiments and tests of the on-board systems and aggregates under complex conditions of a lengthy spaceflight will provide the first experience of operating space apparatus of a new type--manned orbital stations.

The developers of the station "Salyut" were faced with the problem of creating a scientific laboratory existing for a long time in space with changeable crews. The use of spacecrafts in the series "Soyuz" was envisaged for the delivery and return of crews, and the transporting of individual components of equipment, objects and results of research.

In the creation of "Salyut" it was planned to conduct scientific studies on it while manned when the transport craft docks with the orbital block of the station and the crew is located in its compartments, as well as during the flight of the orbital block of the station in an automatic mode without a crew.

According to the plan a portion of the observation results conducted on the station must be transmitted to earth by a radiotelemetric system, while it was provided that another portion be delivered in a transport spacecraft.

Thus the possibility was guaranteed for transporting from orbit to earth used photo and movie materials, photo emulsion blocks, containers with biological objects, on-board logs with scientific observations of the cosmonauts. In the complex of the orbital station created for near-earth orbit of 7 June 1971 were included: the orbital block put into orbit without a crew, and the transport craft with crew to be docked on orbit with the orbital block. The first crew included commander G. T. Dobrovol'skiy, flight engineer V. N. Volkov, and testing engineer V. I. Patsayev who worked on the station for 23 days.

The total weight of the station after docking was 25.6 T, including the weight of the orbital block after it was put into orbit--18.9 T, and the weight of the transport craft in orbit--6.7 T. There were over 1,300 individual instruments and aggregates on board the station. The geometric characteristics of the station: total length in the docked condition 23 m, length of the orbital blocks 16 m, maximum diameter of the orbital block 4.15 m, maximum cross dimension of the station with open solar batteries 11m. In order to fulfill scientific experiments, visual observation, and photo and movie photography there were 27 illuminators in the modules of the station.

In order to transfer the crew from the transport craft to the orbital block and back there is a docking junction. After docking the crew can work and rest both in the modules of the station, and in the areas of the transport craft, by transferring directly through the docking unit without going out into outer space.

On the station "Salyut" for the first time the possibility was provided of repairing and replacing apparatus and equipment in flight by the crew. The placement and layout of equipment and instruments were made with regard for the possibility of access to them in the case of any damages or malfunctions. On board the station there is a set of tools, attachments and certain spare parts.

The results of the scientific and technical studies fulfilled on the station "Salyut" are very extensive. A prominent place in them is occupied by medical and biological studies, astrophysical studies, as well as a comprehensive photographic experiment which belongs to one of the most urgent directions of the applied use of astronautics--study of the environment and natural resources of Earth. The findings graphically indicate the high efficiency of space photography for solving many scientific and national economic problems.

Of great importance are: the first experiment in extra-atmospheric astronomical studies with the help of a stellar telescope controlled by the cosmonauts "Orion," study of cosmic rays using a photo-emulsion block then sent to Earth in a transport craft, and a number of scientific and technical experiments to work out under full-scale conditions systems and aggregates necessary for designing space apparatus.

The especial role of medical and biological studies conducted on board "Salyut" is determined by the principle importance for the development of astronautics of guaranteeing man's lengthy stay under conditions of a space flight. On the station for the first time a set of resources was tested to compensate for the shortage of physical load on the organism of the astronauts under conditions of zero gravity that included a running track, load suits, and certain other components. The biological experiments executed by the astronauts were directed towards solving a number of questions linked to the creation of closed ecological systems of life support for spacecraft of the future.

The first flight of the station "Salyut" made a great contribution to the development and perfection of space technology, was the first experiment in world astronautics to create long-term orbital stations, and graphically showed their great potentialities as multiple-purpose space laboratories capable of providing the solution to many urgent problems in the interests of mankind.

In December 1974 the station "Salyut-4" was put into orbit. On the 268th orbit after 2 weeks of flight of the station it docked with "Soyuz-17," and cosmonauts A. A. Gubarev and G. M. Grechko switched to the station. For a month of the flight the crew fulfilled a large volume of studies and experiments. Upon completion of the work the cosmonauts transferred to a pattern of conservation certain scientific instruments and a number of the service systems, including the system of life support. The station again began to operate autonomously. Three and a half months passed thus. Then the second crew--P. I. Klimuk and V. I. Sevast'yanov worked aboard the station for more than 2 months. During the entire time the systems of the station functioned flawlessly, and studies were conducted according to the assigned program. A considerable volume of scientific research was carried out. This includes fulfillment of medical and biological, technical, as well as a large complex of space-physical experiments designed to solve many questions of astrophysics, solar-terrestrial bonds, geophysics, and research of the earth's natural resources.

The expediency of the realization of certain space studies on the orbital station "Salyut-4" was comprehensively discussed by the scientists. Here both the importance and the significance of the experiment were considered, as well as the possibility of its reliable instrument analysis.

Over 100 different experiments were selected, and they all are of great importance for different fields of science, technology, and the national economy. "Salyut," in particular--an excellently equipped astronomical observatory, equipped with apparatus, capable of perceiving almost the entire spectrum of electromagnetic emissions. Considerable attention was focused on an investigation of the ultraviolet solar radiation with the help of an orbital solar telescope and defraction spectrometer, and the conducting of astronomical observations in the x-ray region of the spectrum. Dozens of solar spectra were obtained mainly from regions of flares on our star. The findings make it possible to investigate the distribution of temperatures, condition of ionization and excitation of atoms, and other physical characteristics of these important and interesting formations on the solar surface. The cosmonauts were assisted by scientists of the ground astronomical observatories. They made recommendations on the selection of objects of observation, and the operating pattern of the on-board apparatus.

Studies of x-ray astronomy aboard the station "Salyut-4" were carried out with the help of two x-ray telescopes--"Filin" and "RT-4."

"Filin" was designed to study x-ray radiation in the region of wavelengths from 1 to approximately 60 Å. It was recorded by four detectors. The telescope had a spectrometer with eight energy channels to analyze the recordable radiation. The sensitivity of the telescope reached roughly 0.01 quantum per 1 cm^2/s, i.e., practically was sufficient to investigate all the known sources of x-ray radiation.

The attachment of the optical axis of the telescope to the stellar sky was provided by two stellar photometers that recorded radiation of the stars in the blue and yellow regions of the spectrum.

Of especial value was information received from the x-ray source in the constellation Cygnus. This source is located in a binary system consisting of a massive normal star and an object invisible in optic rays, whose mass is close to 10 masses of the sun. Possibly this is a "black hole." Its full energetics is indicated by that fact that the luminosity of this x-ray source is 10,000 times higher than that of the sun.

The experimental study of such objects enriches our knowledge about the evolution of stars and the fundamental properties of space and time--the main laws of nature. In the environs of the "black holes" the physical conditions are so unusual that completely new phenomena can be found that are not reproduced under terrestrial conditions. The task of experiments with "RT-4" included study of emissions in the soft x-ray region. The fact is that soft radiation is strongly absorbed by the film of the input opening of the meter. However there is another way--collect x-ray radiation by special optics and direct it to a small meter of photons. The collecting optics can be very extended parabolical mirrors. They are also an excellent filter that does not transmit the hard x-ray radiation.

Cosmonauts A. A. Gubarev and G. M. Grechko observed two residues of "supernovas": one in the constellation Vela, the other--in the constellation Carina. The brightest of the normal stars was also observed. P. I. Klimuk and V. I. Sevast'yanov focused primary attention on stars that were less bright, but possessed a number of specific features, in particular irregularly flashing stars.

During the experiment the list of objects of observations was altered based on data of the ground observatories about the activity of the stars. In addition, in the process of analyzing the collected information sometimes it became necessary to obtain certain additional data, and to recheck the results of previous observations. Then the cosmonauts were given a corrected assignment.

For the rough direction of the telescope axis on the studied source the crew first oriented the station in space, and then maintained the assigned orientation for the entire session of observations. For the further fine adjustment the telescope itself was equipped with a special system of control and astro-orientation.

Among the geophysical studies fulfilled on "Salyut-4," one should primarily name the experiment "Spektr" and "Emissiya."

The task of "Spektr" included measurement of the parameters for the upper atmosphere--density, composition, temperature, and investigation of the interaction of the environment with the spacecraft.

During the flight of the spacecrafts the appearance on their housing of a potential relative to the plasma surrounding it was noted numerous times--the apparatus seemingly was electrically charged. In order to interpret the measurements made on the satellite, and for the normal functioning of the on-board systems it is very important to know the amount of this potential. The positively (or negatively) charged housing will repulse (or attract) ions and, consequently, underestimate (or overestimate) the measured ion concentrations. Having established the laws governing the appearance and the amount of the potential it is easy to consider errors introduced by them into measurements, and provide high efficiency of certain on-board systems.

One of the tasks of the space studies--to explain the features of interaction of particles in rarefied atmosphere with the satellites. The surface of the station "Salyut-4," for example, was continuously bombarded by such particles. An individual impact accompanied by a rebound (reflection) of the atom or molecule cannot provide perceptible results, but continuous impacts result in the deceleration of spacecraft by the rarefied atmosphere.

In some cases this deceleration limits the time of existence of the apparatus in orbit, requiring considerable outlays of energy to compensate for its effect. In other cases--it proves useful and is used to return the long-range space probes to earth, and during their landing on the planet. It is clear that for a precise calculation of deceleration it is important to have a good knowledge of the laws governing such collisions of the particles with the surface of the apparatus. This is especially important in the development of rocket-space systems for multiple use.

The numerous attempts to study in the laboratory the effect of rarefied atmosphere on the movement of a satellite (in the same way as airplane models are tested in aerodynamic tunnels) encountered insurmountable difficulties. The primary one is linked to the need to create streams with velocities reaching 30,000 km/h and over. Another is governed by the sharp difference in the composition of the upper atmosphere from the surface atmosphere and its variability. It remained to move the studies to the actual spacecraft in order to investigate the process of neutral particles hitting its shell.

The experiment consisted of forming beams of atmospheric particles, directing them at different angles at the target, and measuring the characteristics of the stream reflected from it.

The apparatus used to fulfill the experiment consisted of two subsystems: to analyze particles of the approach stream and those scattering after impact with the target. These included analyzers, electron blocks, and a special electromechanical device that guaranteed measurement of the spatial distribution of the particles flying off from the target. The energy of the particles in the undisturbed atmosphere was measured by an immobile analyzer, whose longitudinal axis coincided with the direction of movement of the station. Here the method of changing the inhibiting stress on the network of the analyzer was used.

The range of possible energies was divided into a number of sections. The streams of particles were measured successively in each of them. These data made it possible to determine the spectrum of energies of particles in the approach stream. The work was conducted alternately first with ions, then with neutral particles (preliminarily ionized in the analyzer). Thus, the main physical characteristics of the ion and neutral components of the atmosphere were measured independently, and it became possible to reliably determine the amount and changes both in the temperature of these components and in the potential of the craft in relation to the surrounding ionospheric plasma.

The features of the experiment "Spektr" also include the fact that it permitted a practically simultaneous investigation by one instrument of the characteristics of the neutral and ion components of the atmosphere. The high rate (once in one second) of measurements made it possible to find small-scale nonuniformities in the structure of the atmosphere. Lengthy continuous measurements created the prerequisites for finding large-scale nonuniformities. And the studies with reflected particles in general were set up for the first time. The experiment "Spektr" brought new information which previously was inaccessible to the researchers.

The experiment "Emissiya" was also linked to an investigation of the upper atmospheric layers, primarily the planetary distribution of their temperature and its changes during a magnetic storm.

It is most convenient to judge the temperature of a gas from the width of its spectral lines, linked to the velocities of the emitted atoms. In order to measure the temperature of the upper atmosphere it proved most convenient to use the red line of atomic oxygen. The intensity of its luminescence over the surface of the planet is nonuniform. It is stronger in the polar regions, but individual bright spots appear also at lower latitudes, especially in the zone of increased concentration of electrons near the equator. The luminescence of the red line is intensified during magnetic storms. According to its intensity one can trace how after a magnetic storm from the polar latitudes to the equator wavy oscillations in the upper atmosphere are spread, which encompass thousands of kilometers.

Of great importance is the location of the bands for intensification in the region of the equatorial ionospheric anomaly, which has a strong effect on the spread of radio waves, and on radio communication between the Northern and Southern Hemispheres. It is important to know how the temperature and intensity of luminescence in the upper atmosphere are distributed in order to control manned spacecrafts.

The intensity and width of the red line have been measured from the earth's surface for many years. Optic observations from satellites have noticeably expanded their range. Before the flight of the station "Salyut-4" science had data on the planetary distribution of temperature in the upper atmosphere and its changes during magnetic storms in the period of maximum solar activity. In the period of the minimum, i.e., when the station "Salyut-4" was flying the atmosphere was considerably colder and its heating during magnetic storms occurred under different conditions. This is why it was important to continue such measurements in order to reveal the scope of oscillations in the distribution of temperature in the upper atmosphere with a relatively weak influx of energy from the sun. For this reason the experiment "Emissiya" was set up.

The measuring apparatus consisted of a photoelectric photometer to determine the intensity of the red line and an interferometer with spherical quartz plates measuring its width. Multiple-layer dielectric coatings were applied to the plates. One of them was immobile, the other was fastened to a piezoelectric ceramic to which an alternating voltage was fed that altered the distance between the plates. Here the wavelength was altered of the light transmitted by the interferometer, which permitted recording of the contours of the line and a determination of its width. Before the start of the measurements the cosmonauts installed the instrument on an illuminator and aimed it at an emitting layer.

The fine experimental technique proposed a thorough adjustment and verification of the characteristics of the interferometer. The adjustment of this apparatus from the earth was carried out with the help of a laser. In flight in order to control the tuning there was an on-board optic standard that emitted lines with assigned characteristics. The verification of the apparatus with the help of this standard, as well as aiming of the instrument towards the region of luminescence, especially during magnetic storms, required the participation of the cosmonauts.

The crew of the orbital station "Salyut-4" was also faced with the problem of observing and photographing the earth's surface and ocean in the interests of science and the national economy. As a result a large number of black and white, color and spectrozonal photographs with varying resolution were sent to earth. The photography encompassed many millions of square kilometers of different regions of our country.

The flight of the station "Salyut-4" once again showed with all convincingness the promising nature of the main path for the evolution of astronautics--the creation of orbital stations which have not only enormous scientific but also ever greater practical importance, by promoting the solution of the most important economical, ecological and other tasks facing mankind.

At first glance it can seem strange that in the age of highly developed technology, automatics and remote control that a man should be on board a spacecraft, especially since automatic machines have demonstrated their merits fairly convincingly and often also advantages. It is no secret that an investigation of outer space is linked to a great outlay of resources. And in this respect the automatic apparatus are considerably more suitable, especially for studying the moon and planets in the solar system. Saturated with diverse scientific apparatus they make it possible to obtain, and then to transmit to earth on radio telemetric and television channels a large volume of information about these regions and the physical processes occurring there. In our country automatic apparatus of the returnable type have been created which are capable of delivering results of measurements to earth for their subsequent processing.

When the payload of the space objects include the weight not only of man himself, but of all the life-support systems, the framework of the scientific program is inevitably constricted, and the quantity of strictly research instruments is limited. Considerations for a random danger awaiting man in space are always added to these discussions.

However all of this still does not mean that one can generally do without man in space flights.

The main task linked to penetration into space, at least in the near future, consists of an ever deeper knowledge of the world surrounding us. Even now outer space has been converted into an important laboratory of modern science, where one can make detailed studies of different processes and phenomena, including those not yet known to scientists. But this means that as space is penetrated the researchers inevitably will face more often problems which were not formulated previously, and therefore in order to solve them a basically new approach is required every time. In this respect man possesses unique potentialities.

One should not forget also about the subconscious activity of the human brain, about intuition which lies beyond the potentialities of cybernetic machines. For both the subconscious and intuition play an extremely important role in the process of the scientific study of nature. Only man can effectively study the unknown. He possesses the unique capabilities of not only observing, but also accumulating and analyzing the obtained information, storing it in his memory and using it for the rapid making of a correct decision in unforeseen circumstances. There is no machine made by human hands that is capable yet of doing this.

The modern automatic machines cannot study that which basically cannot be reduced to an already obtained knowledge. They are capable of studying only such processes and phenomena that are already familiar to man in their main features. It is true that recently the scientists have carried out extensive work on the creation of so-called heuristic programs for electronic computers. Detailed programs are being developed on the basis of a generalization of the research activity of people. In the ideal machine, equipped with a heuristic program the process of scientific research in a certain field must be implemented independently. However the real potentialities of such programs are still comparatively small.

We will return to specific examples. Take, for example, the problem of studying solar flares that plays a primary role in the prediction of radiation safety of space flights. Now these studies are carried out with the help of automatic instruments. Usually the automatic machine is guided according to the optic center of the flare, which often has a very fantastic and indefinite shape, and can fall from the field of vision of the instrument. Sometimes in different regions of the sun simultaneously two-three flares develop. The automatic machine records something averaged, and the information will be inaccurate. The cosmonaut on the basis of personal experience and creative initiative can make an operational change in the program of studies, and provide a considerably more complete picture of the optic observation, determine the section of generation of the flare, study the concomitant phenomena, and so forth.

One should also note the especial role of the cosmonaut-scientist in studying short-term irregular processes in space. When only automatic machines observe them many data can be lost among the long-term information. The specialist not only focuses attention on them, but also catches the concomitant phenomena in the complex of studies.

Even the normal visual observations from space have exceptional merits. The workers of agriculture, fc⁻ example, a.e interested in the condition of the soil in the preplanting period, its moisture content, temperature--and all of this on giant territories. Sailors are interested in the condition of the ocean surface, its wave action, and fishermen--in the presence of fish in a certain region. At the same time the information must be rapid, especially if this concerns data on different elementary phenomena. And in this respect the presence of a specialist aboard the craft is invaluable. Not only will he instantly evaluate the situation, but also make qualified conclusions on the development of a certain meteorological process, will give a storm warning, and so forth.

The cosmonaut-scientist can make rapid changes in the program of studies from the viewpoint of selecting studied objects. By using diverse and fairly complex apparatus he provides a considerably fuller picture of the optic observation. We will give such an example from the field of meteorology in order to explain.

One of the fundamental problems facing science--energetics of the earth, i.e., the influx and expenditure of heat of our planet. The scientists are interested in how much solar radiation is absorbed in different regions of the earth, how it is distributed over the earth's surface, and how much energy the earth gives off into space.

This is that information that meteorology extremely needs, since precisely the influx and expenditure of energy determine the changes in weather and climate over the entire globe. The main barrier to heat emission--the cloud cover of the planet. Therefore it is necessary to make a thorough investigation of the optic properties of its different forms. Daily the satellites in the system "Meteor" supply us with an enormous quantity of information in the form of television and the infrared images of the cloud cover. However not all the forms of clouds can be clearly recorded on these photographs. Thus, cirrus are almost not noticed on them, and silver clouds are not recorded at all. This problem is only in the realm of a qualified observer on board a spacecraft.

Studies of recent years have shown that aerosols have a significant effect on weather and climate, these are the smallest particles both of terrestrial, and space origin that are flying in the atmosphere. One of the most promising methods of determining the spatial distribution of aerosol in altitude, as well as its optic characteristics--observation and analysis of the crepuscular aureole of the atmosphere. The solution of such a task with the help of automatic machines is still difficult. Here man is also needed.

The presence on board a spacecraft of a cosmonaut is important for meteorologists for yet another reason. Currently scientists have come to such a stage of development of studying processes determining weather and climate on earth where one can with the help of measurements made from satellites determine the quantitative meteorological parameters of the atmosphere. Such parameters in the first place are temperature and air humidity. One should note that a quantitative prediction--the most precise, and consequently, the most promising. With the help of electronic computers one can predict how the atmosphere will be changed with these starting data. It is natural that measurements from satellites here have an indirect nature, since they fly at an altitude of several hundreds of kilometers. We are interested in the layer of atmosphere that is only about 30 km thick, where the weather is "cooked." The situation is analogous to that existing in astrophysics. All that we know about the sun and stars has been obtained from data of studying their emissions. Due to the advances in rocket and space technology it has become possible to lift research apparatus into space. By measuring there the emissions from earth in different regions of the spectrum the scientists find, in particular, the parameters they are interested in.

Of course this is a very complex task. For example different distributions of temperature and altitude can correspond to one amount of radiation. And even small errors in the measured amount result in large errors in the final results. Therefore in order to obtain such experimental data it is necessary to have very complex apparatus, that can be controlled by a skilled specialist on board a spacecraft.

Regardless of where the studies will be carried out--on manned craft or on automatic stations, it is necessary to create specialized scientific apparatus. At the first stage of exploring and developing techniques for research the direct participation of cosmonaut-scientists would produce a great effect. The specialist on board a spacecraft will make a complete and detailed analysis of the observed phenomenon, will reveal the objects and processes which are of greatest interest for the study, will generalize the readings of the instruments, will change, if required, the program of measurements, and will continue the experiment in the necessary direction. The scientists can select the optimal apparatus necessary for man in the final analysis to conduct detailed studies, and the pattern of its operation.

As we see the active participation of man in studying outer space is necessary. Therefore the steps undertaken in our country for the laying of more certain and reliable paths for man's penetration into space are completely natural.

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Chapter 7 - Some Results of Space Research

It is known that the cost of space flights is fairly high. However the outlays for the development of space are not senseless. Successes in its development have promoted a sharp rise in a number of fields of science and technology: biology and medicine, astronomy and aerodynamics, radio engineering and automatics, gas dynamics and electronics.

The programs for the flights for the majority of Soviet satellites are closely linked to the solution of a number of national economic problems--investigation of the atmosphere and earth's magnetic field, establishment of communication through space, navigation with the help of satellites, exploration of minerals, and so forth.

What does study of space give man?

Cosmic Rays

The earth is subject to the continuous action of a continual stream of charged space particles, whose velocity of movement is close to the speeds of light.

Our ideas on the nature and properties of cosmic rays are becoming more and more complete.

The first information on cosmic rays belongs to 1912 when the Austrian Hess, while conducting experiments on a balloon advanced the hypothesis that radiation of very great penetrating ability falls on the border of the atmosphere from the world of space. Hess' hypothesis was supported ten years later by Millikan who called the hitherto unknown rays cosmic. According to Millikan's hypothesis cosmic rays develop by means of energy released during the synthesis of heavy elements from primordial hydrogen distributed in the universe, and these--photons of enormous energy that possess great penetrability.

The experiments of Bote and Kol'yerster resulted in the hypothesis that primary cosmic radiation consists not of photons, but rather of charged particles. Here the interaction of cosmic rays with the substance results in complex processes within the substance, as a result of which many secondary particles are formed. The discovery by Anderson of the positron was a considerable advance in this direction. In the opinion of Dirac this particle could not previously be found as a consequence of its very short life.

When a positron meets an electron both the particles are annihilated, their mass is transferred into energy which is emitted in the form of photons.

Carlson and Oppenheim almost simultaneously explained the nature of showers of cosmic rays. According to their theory the development of a shower occurs by means of the birth of pairs by photons and emission by photons by electrons during braking in a field of nuclei. These processes occur near the atomic nucleus, without producing changes in its structure. In each elementary act only two particles develop, and although the shower-forming radiation consists of electrons and photons, the particles that possess great penetrability cannot be considered electrons. Neddermeier proposed that these are new particles with a single charge and mass greater than the mass of a normal free electron, but considerably smaller than the mass of a proton (consequently they were called μ-mesons).

The most important stage in the investigation of the new world of particles began in 1947 with the discovery of the π-meson which proved to be parental in relation to the previously known μ-meson. In the destruction of the π-meson, in addition to μ-meson another neutral particle is born. The mass of the latter is much smaller than the mass of the electron. There are two such neutral particles with practically zero mass--the photon and the neutrino. It is extremely complicated to find the neutrino, since it interacts with substances very weakly; the photons are recorded according to the secondary electrons emitted by them in the process of formation of pairs. After not finding photons among the products of μ-meson breakdown the physicists drew the conclusion; the neutral particle with zero mass emitted during the breakdown of π-mesons is the neutrino.

In the same year Oppenheim advanced a hypothesis that subsequently proved correct: the neutral mesons can be rapidly broken down into photons that are included in the composition of cosmic rays observed in the atmosphere.

The new experiments showed that the cosmic particles that interact the most strongly in the atmosphere are protons, neutrons and π-mesons that did not succeed in breaking down into μ-mesons.

The number of protons, neutrons and π-mesons rapidly increases with altitude, therefore in order to study nuclear interactions attempts were made to conduct experiments as high as possible. Apparatus of sounding balloons was perfected, that trailed for days the air ocean at altitudes up to 30 km. Here the remarkable diversity in the previously unknown short-lived "elementary" particles was explained. In 1953 they were divided into two groups that received the name of heavy mesons and hyperons, whereby both could be neutral, as well as charged. Heavy mesons are lighter than protons, but heavier than π-mesons; hyperons are heavier than protons.

In the 1950's, as if summing up the main landmarks in the evolution of the physics of cosmic rays a single pattern of all phenomena linked to these rays began to be formed.

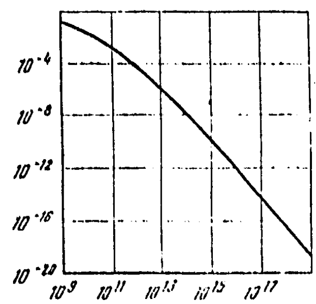
Now it could be fairly confidently stated that a number of the hypotheses listed above were erroneous. At the same time many conclusions were confirmed: these were the presence in the composition of cosmic rays in the atmosphere of electrons and protons of great energy, the assertion in relation to the birth of mesons in the atmosphere, and the existence of different types of mesons.

The launching of artificial earth satellites opened unique potentialities for the setting up of basically new experiments in outer space. It became possible to go beyond the limits of the atmosphere, and then also beyond the limits of the action of the earth's magnetic field, and to investigate the primary cosmic radiation directly.

As was already stated, in outer space there are particles of practically any energy. The basis of the primary cosmic rays is protons, electrons, and in smaller quantities--nuclei of atoms of different chemical elements. According to the modern idea the trajectories of these particles, in approaching the earth, are bent by the earth's magnetic field. When they collide with nuclei of atoms of atmospheric gases breakdown of both the "missile" and the "target" occurs. Protons and neutrons with high energy are found in the decomposition products, which in turn interact with other nuclei in the atmosphere. A portion of the energy of the primary particle goes for the formation of new short lived particles, such as μ-mesons and heavy mesons.

An investigation of the interplanetary field with the help of spacecraft made it possible to reveal a number of new phenomena, and radically review the ideas on the processes occurring in the environs of Earth. Observations from satellites showed that the intensity of the low-energy portion of cosmic radiation is not constant in time and is linked to the activity of the sun. Thus, in the period of the grandiose flare on the sun which occurred on 23 February 1956 the intensity of cosmic rays rose roughly in 20 minutes 25-50-fold as compared to the normal level. It is assumed that this phenomenon was governed by a stream of high-energy solar cosmic rays--particles, primarily protons, emitted by the sun during the flare.

Further studies of these rays have the goal of explaining the mechanisms of their generation on the sun, conditions of spread in the interplanetary space, and emergence from the solar system.



Energy Spectrum of Primary Cosmic Rays
Along the vertical--number of particles per 1 cm^2 per unit (1 rad) of solid angle in 1 s, along horizontal--energy in eV

Considerably more often, almost monthly, there are less powerful flares of cosmic rays with energies 100-500 MeV. However the magnetic field of Earth deviates the particles with such energy, moreover they are strongly absorbed in the earth's atmosphere; to record them it is necessary to carry measuring apparatus to great altitudes with the help of balloons and satellites. Precisely the satellite apparatus made it possible to record solar cosmic rays of the lowest energy--up to 1 MeV. Here to a considerable measure the charge composition, and energy spectrum and nature of spread of these rays in space were successfully explained.

Besides the light, heat and cosmic rays the sun continuously emits streams of hydrogen plasma--solar wind. This stream of ionized gas of low density is the outer portion of the solar corona that has a fairly high kinetic temperature. Escape of plasma near the sun occurs comparatively slowly (with velocities 10-20 km/s), but the farther from the sun the velocity rises 20-70-fold.

The stream of plasma qualitatively differs from the stream of charged individual particles, since in it the key role is played by forces of electrostatic interaction between ions and electrons. The plasma is characterized by the fact that the energy of the electrostatic interaction of the charged particles comprising it is greater than the energy of the thermal movement. Despite the small concentration of particles in solar wind the electrical field binds them. The magnetic field also affects the behavior of particles in plasma.

The high electrical conductivity of plasma results in a strong bond of the field with the medium, as a consequence of which the magnetic field can be viewed as if "frozen into" the plasma. The solar wind seizes the magnetic field of the sun, extending it along the direction of its movement. The rotation of the sun gives the force lines of the magnetic field the shape of Archimedes' spiral.

There are a number of hypotheses on the origin of galactic cosmic rays. Certain scientists hypothesize that millions of years ago in the center of the galaxy an explosion occurred of enormous strength. Its energy was scattered in the form of different emissions--visible light, radio waves, particles. A portion of this energy was transmitted to cosmic rays. Within millions of years the fastest of the particles reached Earth. Literally in recent years it has been established that the age of the galactic cosmic rays does not exceed 100 million years, while the latter explosion in the center of the galaxy occurred no more than 10 million years ago.

Other scientists assert that a large portion of the cosmic rays were born during less powerful explosions of super nova stars, which in the environs of our solar system occurred in several hundred years. In the process of explosion a quantity of energy was released equivalent, possibly, to the energy contained in the entire mass of the sun. The particles formed as a result are accelerated as a consequence of the electromagnetic processes similar to those that occur in solar flares.

The area occupied by the magnetic field of Earth is called the earth's magnetosphere. Its border in the magnetically calm time is located on the diurnal side at a distance about 10 earth radii, and on the shaded side is removed a distance three times greater.

Three regions that differ in their properties are defined for the real geomagnetic field: internal, external and boundary.

In the environs of Earth the magnetic field resembles an undisturbed dipole field of a uniformly-magnetized sphere. The center of this dipole is shifted roughly by 500 km towards the Eastern Hemisphere. The geomagnetic axis, in addition, does not coincide with the axis of revolution of Earth. The real magnetic field differs fairly significantly from the strictly dipole. It is characterized, in particular, by considerable local anomalies, whose effect with altitude rapidly disappears. Here, as shown by measurements on the automatic stations "Luna" and satellites, it depends also on external factors.

Daily variations are found in the magnetic field, that develop mainly during the day (solar variations). There are variations with period, equal to half of a lunar day, and systematically changing with the phase of the moon (lunar variations).

There is the hypothesis that the solar-diurnal variations are governed by the electrical currents in the upper atmosphere that occur as a consequence of its heating, while the lunar-diurnal are determined by tidal movements.

The measurements have shown that starting with a certain distance from the center of Earth (6-9 of its radii) the magnetic field strongly differs from the field of the dipole, characterized by higher intensity.

The boundary area of the magnetosphere extends several earth radii and is distinguished by a sharp drop in field intensity, fluctuations, and a gradual transition to an interplanetary field. On the diurnal side a front of standing impact waves is found that separates the magnetosphere from the undisturbed solar wind.

At great distances on the diurnal side the magnetic field of Earth is squeezed out by a stream of plasma of solar wind, constricting the force lines such that on the interface the pressure of the stream is equalized with the pressure of the magnetic field. The magnetic field of Earth on the nocturnal side is subject to even greater distortions. It has been established that starting with the distance of several tens of thousands of kilometers the field of Earth gradually passes into a magnetic tail, that stretches far beyond the limits of the moon.

The geomagnetic tail is divided by the plasma layer with small intensity of the magnetic field.

Albedo and Atmosphere of Earth

The satellites render great assistance in studying the stream of radiation emitting from Earth. The reflected and natural radiation of Earth are distinguished according to their spectral characteristics. The border between them is wavelengths in the area $4\,\mu m$, whereby the area of larger wavelengths encompasses the natural radiation of Earth.

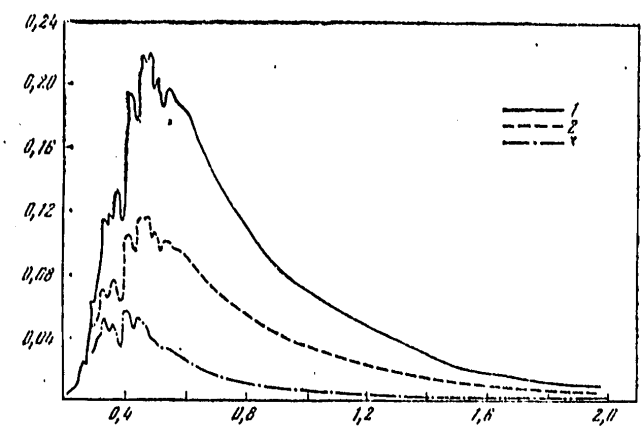
Based on numerous measurements it has currently been established that the amount of reflected solar radiation (albedo of Earth) averages 35%. The remaining 65% is absorbed by water and the earth's surface, and is reemitted in the long-wave section of the spectrum.

The reflecting ability of individual elements of the earth's surface fluctuates in broad limits and depends on seasonal variations. Soils have, for example, albedo from 0.03 to 0.08, sand--from 0.25 to 0.4 in the greater portion of the visible range. The albedo of freshly fallen snow--from 0.6 to 0.9; the albedo of the whitest clouds--up to 0.8 in the visible section of the spectrum, while beyond its limits due to the absorption by water and vapors it is reduced to 0.5 at wavelength 2.5 μm. It is characteristic that the amounts named here of the albedo have an approximate nature, since they significantly depend, for example, on the amount of the angle of incidence of the incoming radiation.

From the general mean calculated amount of albedo of the earth roughly 70% is governed by reflection of the cloud cover usually covering half of the earth's surface.

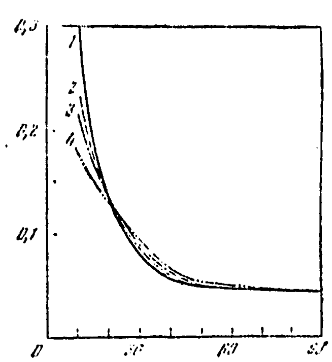
The reflecting ability of the aqueous surface significantly depends on the altitude of the sun.

The complexity of the problem of measuring the earth's albedo consists of the fact that the thermal radiation perceived by the space apparatus is only partially linked directly to the earth's surface and clouds. Carbon dioxide and water have strong absorption bands in that range of wavelengths in which



Radiation Reflected by Earth
Along vertical--spectral intensity, W x cm^{-2} μm^{-1}, along horizontal--wavelength in Å;

Key:
1. **Solar spectrum**
2. **Spectrum of reflection of Earth with sky covered with clouds**
3. **With cloudless sky**



Theoretical Reflecting Ability of Aqueous Surface in Calm State (1), with Light Wind (2), with Wind about 5 m x s^{-1} (3), with Strong Wind (4)
Along vertical--amount of albedo, along horizontal--altitude of sun in degrees

the earth also emits, and thus, has a strong effect on this radiation. In the area of the spectrum 8.3-12.5 μm the earth's atmosphere has a window of transparency, however also in this range a certain absorption of radiation by dust and water vapor is noted.

The atmosphere is a gas shell surrounding the earth. In the life of mankind it plays an exceptional role. We breathe atmospheric air, the air ocean protects us from the primary cosmic rays, x-ray and ultraviolet radiation of the sun, and meteorites. From here it is understandable why the scientists are interested in the properties of the atmosphere.

In accordance with the nature of the change in air temperature with altitude the atmosphere is divided into a number of layers or spheres: troposphere, stratosphere, mesosphere, thermosphere, and exosphere which are divided into transitional layers.

The lowest sphere--the troposphere, and its upper border fluctuates about 11 km. The densest air is in the troposphere--it has 90% of the entire mass of the atmosphere. Here phenomena occur which form the concept "weather" primarily formation of clouds and precipitation. The troposphere is characterized by a decrease in temperature with altitude--6.5° for each kilometer. The stratosphere is above. It stretches roughly to 50 km. Although the stratosphere contains less than 1% of the atmospheric mass, it is distinguished by diversity of the physicochemical processes and fulfills the role of a natural protective screen. Precisely here the ultraviolet, x-ray and corpuscular radiation of the sun is absorbed, while the ionization of the upper atmosphere by solar short-wave radiation makes long-range radio communication possible.

The complex processes of thermal and mass exchange in the upper atmosphere determine the dynamic nature of this medium and have an effect on the condition of the atmosphere at the earth's surface, and the formation of climate and weather on earth.

Over a number of centuries science has accumulated data on pressure, temperature, density and the gas content of the earth's air shell. But until recently only a thin surface layer of air was accessible for its thorough study. The area of research was somewhat expanded with the appearance of airplanes and aerostats. Then in order to investigate the atmosphere pilot balloons and radiosondes began to be used that transmitted over the radio data from altitudes up to 30 km. By using indirect methods of research of the upper atmosphere (study of the spread of acoustic waves from super powerful explosions and observations of meteors) the scientists in the 1930's-1940's explained the general laws governing changes in density, pressure, temperature with altitude and they obtained the first spotty data on the composition of the upper atmosphere. The scientists came to the conclusion that the atmospheric temperature continually is reduced up to altitudes 8-18 km, while above that it is maintained practically constant. On the whole it was considered that the stratosphere is a layer that has comparatively little movement.

Some of the ideas were altered even before the appearance of satellites. Thus in the stratosphere strong air currents were found and peculiarities in the spread of a sound wave from strong explosions. The waves were heard well next to the site of the explosion, then a zone of silence occurs, and then a zone of audibility. The natural reason for such a phenomenon, in the opinion of the scientists, could be the increase in temperature of the atmosphere at great altitudes.

The research rockets and artificial earth satellites helped to answer this and many other questions. Here the classic methods were used for measuring parameters of the atmosphere (manometric, thermometric, and so forth). The wind was studied by discharging metallized radar targets. A mass spectrometer was used to analyze the atmosphere.

On high-altitude rockets the scientific apparatus was placed in an ejection container-automatic machine that made it possible to make measurements of parameters in the unpolluted section of the atmosphere. In order to study the composition of gas samples were taken in glass cylinders. Stabilized reference containers also began to be used that guaranteed a constant orientation of the measuring instruments in relation to the incident stream.

Below 20 km, where lengthy existence of satellites is impossible, studies are conducted mainly with the help of rockets. However they make it possible to trace the dynamics of changes in the atmospheric parameters mainly only for altitude, since measurements of parameters for time require launching of a great number of rockets in the course of one experiment.

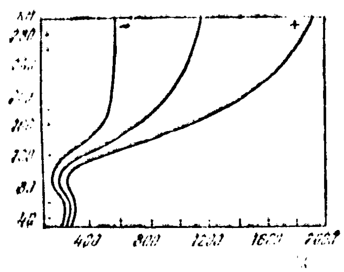
At altitudes above 200 km measurements with the use of satellites that encompass with their orbits practically the entire planet are widely used.

The modern ideas about the structure and variations in the parameters of the neutral atmosphere at great altitudes are based mainly on data about the evolution of satellite orbits, which has made it possible on the basis of aerodynamic calculations to determine the braking force, and consequently, atmospheric density.

We will dwell briefly on the results of research of the upper atmosphere obtained in recent years with the help of satellites.

Temperature of atmosphere. The mean amounts of atmospheric temperature for the Northern Hemisphere at altitudes up to 300 km are given in the figure. It gives the limit deviations in temperature from the mean amount. It is characteristic that in the range 30-50 km the temperature is increased, since almost the entire ultraviolet section of solar radiation is absorbed near the upper border of the ozone layer corresponding to these altitudes.

The total quantity of ozone in the atmosphere is insignificant; the thickness of its layer relative to standard atmospheric conditions does not exceed several millimeters. However the value of ozone is enormous: it abosrbs the ultraviolet radiation and thermal radiation emitted by Earth, preserving organic life on our planet.



Distribution of Temperature in Altitude (30-300 km) and Limit Deviations from Mean Amount (-, +)

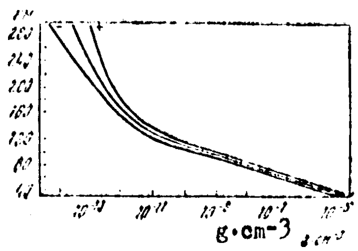
In the mesosphere the temperature is reduced from zero to 90°. In the thermosphere at altitudes above 90 km the temperature of the air continuously rises, reaching at altitude 300-400 km 1,000°C, and continuing to rise with altitude to 2,000-3,000°C. However, as a consequence of the strong rarefaction of the air the physical concept of temperature of the environment here has a nominal nature, characterizing only the velocity of molecular movement.

During the day the atmosphere is heated, but at night is cooled, therefore there are diurnal variations in the temperature profile. The maximum and minimum of these variations occur at 04.00-06.00 and 14.00-16.00 local time. For example, at altitudes above 200 km the temperature is changed at night from 600 to 1400, during the day--from 1200 to 2,500 K. Thus, the maximum drop in temperature on the upper border of the thermosphere from the nocturnal conditions in the minimum to the diurnal in the maximum of solar activity can reach 2,000°.

The seasonal variations governed by the radiation balance are noted up to altitudes 60 km. Above the pattern is altered the opposite--the winter temperatures are above the summer.

Density of atmosphere. The density of the upper atmospheric layers is determined, as already mentioned, by observations of the braking of satellites and change in the period of their rotation around Earth. On a number of satellites instruments have been installed to measure atmospheric pressure.

It has been found that the atmospheric density is considerably higher than proposed on the basis of theoretical calculations and previous experiments. The nature of the distribution of mean density in the range of altitudes 30-300 km, and the limit deviations from the mean amount are presented in the figure. With altitude the density of the atmosphere drops, having significant seasonal and diurnal variations. Thus the seasonal variations have maximum values at altitudes 65-75 km, reaching 25% in the high latitudes and 15%--in the middle. A decrease in variations of density at great altitudes, in the opinion of scientists, is linked to the reverse course of temperature disturbances which at altitudes over 60 km in summer are lower than in winter. The studies conducted on the satellites in the series "Cosmos," showed that the diurnal variations are observed in broader limits. Thus at altitude 200 km density from night to day rises 1.8-fold, at lower altitudes--1.7-fold. The diurnal variations have a regular nature, appearing more sharply at the lower latitudes with a reduction in solar activity. Annual and semiannual variations in density are noted that are linked to disturbances of Earth's magnetic field, as well as a 27-day periodic variation that is determined by the equatorial period of solar rotation.



Distribution of Atmospheric Density in Altitude (30-300 km) and Limit Deviations from Mean Amount (-, +)

Study of the atmosphere is important also from the viewpoint of investigating its ion and molecular composition, and electron concentration in the ionosphere. The latter makes it possible to reveal factors affecting the nature of spread of radio wave systems of long-range surface and space communication.

In order to determine the ion composition of the atmosphere mass spectrometers are used which with the help of an electrical or magnetic field separate the ions according to masses.

A number of mass spectrometric analyses of the neutral composition of the upper atmosphere conducted mainly at altitudes 100-200 km with the help of rockets confirmed the effect of the gravitational division of argon and molecular nitrogen in the atmosphere above 100-200 km, and also permitted data to be obtained on temperature and partial concentration of molecular nitrogen to altitudes 400 km.

Analysis of the ion composition of the upper atmosphere made from measurements back on the third Soviet satellite in the range of altitude 225-980 km showed that in the daytime here positive ions of atmospheric oxygen dominate. Positive ions were also recorded with mass number 14, which could be identified with ions of atomic nitrogen, positive ions of atomic isotope of oxygen with mass number 18, as well as positive ions of nitic oxide. Here it was revealed that the ion composition of the upper atmosphere is significantly altered depending on altitude. The percentage content of heavy ions of molecular oxygen, nitric oxide and molecular oxygen drops with altitude, thereby most intensively in the interval 225-270 km, and at altitudes above 400 km the content of ions of molecular oxygen is 1,000 times lower than the ions of atomic oxygen.

With the help of the series of satellites "Elektron" at altitudes 400-1,200 km a large number of mass spectra were obtained for ions of hydrogen, nitrogen, helium and oxygen, and considerable variations were also found in the ion composition with geographical latitude. It was revealed that the ions of helium in the temperate latitudes of the Northern Hemisphere in a period of low solar activity are only a small component. This result altered the existence of the view on the structure of the external ionosphere of Earth, according to which helium ions at altitudes 1,000-2,000 km form a hypothetical "heliosphere.". It was found that no such shell exists in the earth's ionosphere.

Study of the parameters of the upper atmosphere continues. Precise knowledge of them has enormous practical importance. Thus, the distribution of density over altitudes is considered in a calculation of optimal criteria for putting booster rockets and earth satellites into the calculated orbits, in the creation of optic objects with systems of precision orientation, and in solving problems of controlling flight in the upper atmospheric layers.

Astronomical Observatory

One of the most ancient sciences, astronomy, for a millenium could only passively study light coming from the planets and stars, and from it create its ideas on the physical properties of the celestial bodies. Being on earth the astronomists had to reconcile themselves with the atmosphere that impaired observations of the sky.

Radiation of celestial bodies penetrates the earth in two windows of transparency: optic, stretching in the range of wavelengths from 0.3 to 1-2 μm, and radio window--from several millimeters to 10-30 m. The main spectrum of cosmic radiations is absorbed by the atmosphere. Thus, ultraviolet radiation is absorbed by ozone at altitudes 30-70 km in the range 0.3-0.18 μm, by molecular oxygen at altitudes below 120 km in the range 0.18-0.1 μm, and by atomic oxygen and nitrogen at altitudes up to 200 km in a range less than 0.1 μm.

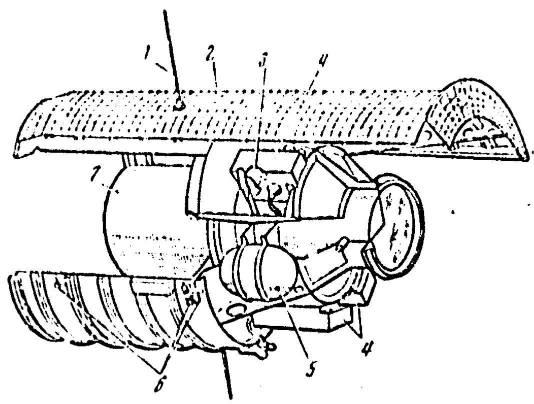
Long-wave cosmic radio emission is reflected by the ionosphere located also a great distance from Earth.

A significant obstacle in astronomical observations through the atmosphere is also its turbulence. Therefore the stars are viewed in a telescope eyepiece not in the form of a clear defraction disk, but in the form of blurred spots; at the same time the brightness of the image is reduced. Stars located low above the horizon are observed especially poorly through the thickness of the atmosphere. The light is refracted in the atmosphere, and the spot alternates with spectral bands.

For this reason linear resolution for the surface of the moon is 1 km, for the surface of Mars--150 km. The turbulence has an especially strong effect during the operation of telescopes with mirrors over 2-3 m in diameter, which serves as an additional obstacle to the use of modern giant telescopes.

As air travel developed, possibilities appeared for lifting telescopes with the help of aerostats. From an altitude of 20 km clear photographs were made of "grains" of the sun 0.3' in size. Even greater possibilities were presented to astronomy by the use of satellites.

What requirements are made of a telescope installed on a spacecraft? In principle they do not differ from the requirements for the modern surface telescopes. In the center of the mirror theoretically an angular resolution can be provided on the order 0.006" which will make it possible to distinguish at distance 500 km objects with linear size 1 cm. However practically with the diameter of 2 cm mirrors can be made with resolution 0.2". With resolution of a telescope 0.1" and with possibility of using long exposures one can observe stars up to the 23rd stellar size. In future years orbital observatories may appear with an aperture of the primary mirror up to 3 m and angular resolution up to 0.01" in the ultraviolet region of the spectrum.



Schematic Image of Small Astronomical Satellite

Key:

1. Antenna of telemetric system
2. Solar elements
3. Solar gage for system of precise orientation
4. Blocks of electronic equipment
5. Cylinder with gas for control jets
6. Jet for decelerating rotation and controlling listing and velocity
7. Telescope

The satellites designed to carry out astronomical observations can have an instrument compartment of the observatory equipped with a radio engineering system of automatic docking, mooring device and locked chamber permitting approach and mooring of a manned spacecraft and access to it by cosmonauts. The observatory can be docked to a manned orbital station.

A draft space laboratory-satellite for medical and biological, geophysical and astronomical studies is known from literature. On the satellite with a crew of 4-6 people a telescope in particular can be installed.

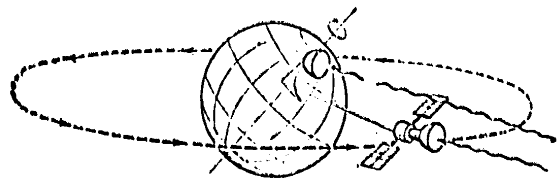
In accordance with another such plan of space astronomical observatory the crew is placed in a special nose capsule that serves at the same time to save the crew in case of an accident. After the satellite has gone into orbit the fuel tank that is released from fuel is drained and filled with compressed air. The crew also moves here, using the tank as a working module.

Astronomical studies in space will, apparently, be conducted in different ranges of wavelengths. However these will primarily be spectral and photometric observations in the ultraviolet, infrared and submillimeter regions of the spectrum. As recording elements of the telescope photomultipliers and electron-optic transformers can be used, photomaterials and television transmitters. It is interesting that the American orbital astronomical station launched in 1968 into orbit with altitude 800 km and equipped with optic telescopes with diameters up to 40 cm made it possible to obtain data in the ultraviolet region of the spectrum about 10,000 stars. If the diameter of the telescope is increased to 3 m, the number of studied objects can rise to a million.

The objects of x-ray astronomy can be the thermal radiation of plasma, the reverse Compton effect of electrons on infrared photons, or synchrotron radiation of relativistic electrons in magnetic fields. To study them proportional gas-filled counters can be used with a window made of beryllium (thickness to 100 μm) or organic films--maylar, formvar, and polycarbonate (up to 10 μm thick). With the help of proportional counters one can determine the stream from a source, its spectrum, angular size and position. However as a consequence of the weak resolution of these sources the spectrum is determined very roughly. The angular position of a fairly bright source in combination with a modulation collimator can be obtained with accuracy up to 10".

The already obtained results are promising. The satellite "Uhuru" (United States) and the rockets launched to altitude up to 200 km with similar astronomical apparatus found over 50 discrete x-ray sources, of which no more than 15 were identified with the known optic objects.

In order to conduct studies in the radio astronomical region of the spectrum the opening in space of antennas whose diameter can reach several kilometers presents definite technical complexity. One antenna can be taken into space, while the other remains on earth. Although the resolution of such a radio interferometer can be fairly high--up to 2×10^{-5} angular seconds, its creation is linked to great technical difficulties that include precise orientation and precision synchronization of both antennas separated by thousands of kilometers.



Scheme of Space Radio Interferometer

Modern meteorology contains fou. large fields: climatology, synoptic meteorology, aerology and aeronomy. Climatology studies a many-year pattern of weather from individual regions of the earth, setting as its task the determination of the characteristics of normal weather conditions. Synoptic meteorology studies the general processes in the atmosphere that develop on large spaces. It develops methods of weather forecasting. Aerology and aeronomy study the upper layers of the atmosphe.a and the ionosphere.

Observations of changes in weather are made by the hydrometeorological services of different countries that daily exchange information over the radio and telegraph that is accumulated with the help of a vast network of hydrometeorological stations located on dry land, water and in the air. Only within the limits of our country there are over 4,000 such meteorological stations and 7,500 meteorological posts, and hydrological observations are carried out in 6,000 points. Over 2,000 stations sound the atmosphere with radio waves. Information of special airplanes and ships is used. And all of this enormous quantity of information rapidly enters the USSR Hydrometeorological Center. The meteorological stations during the day make several measurements of the velocity and wind direction, temperature, air humidity and many other parameters that characterize the current condition of the atmosphere. By analyzing them the scientists composed synoptic maps and predict the weather. Many hours in advance, and sometimes even days the captains of ships are warned of approaching storms, the workers of agriculture--about possible frosts and rains, and flyers--about storm fronts, wind strength and visibility.

However, no matter how numerous the arsenal of meteorological stations and how rich the experience of many years of observation, no matter how advanced the modern instruments, all of this is insufficient for a precise weather forecastin.. This is explained, first, by the fact that over 70% of the entire surface of the earth is covered with oceans and seas, while a considerable portion of the dry land is desert, mountains and polar regions, where it is difficult or even impossible to place stationary meteorological points. Second, even with the extant stations it is very complicated to make observations. We are located at the very bottom of the air ocean, and therefore know best of all what happens in the lower layers of the atmosphere with thickness 30-40 km. The air currents trap great spaces not only in the area, but also in altitude, and observations of them at individual points do not provide a complete and viable picture.

Therefore many elementary phenomena are so unexpected and sometimes tragic. Thus in 1963 the cyclone that came from the Pacific Ocean to the coast of the Sea of Okhotsk produced unprecedented snowfalls that disrupted telegraph and railroad communication; on the same days in West Europe unexpected colds resulted in the death of over 700 people. We will not soon forget the earthquakes in Tashkent and Chile, the floods in France and Yugoslavia that occurred in the last decade.

Many misfortunes caused by the elements could be avoided if we knew in time the development of elemental upheavals. To learn to forecast these phenomena--is the first task, and the second even more complicated task--to learn to control the climate mechanism. Then one will be able "upon order" produce rains and eliminate fogs, exclude droughts and floods, cyclones and hurricanes.

The launchings of the artificial earth satellites, especially the Soviet satellites in the series "Cosmos" and "Meteor" and the American "Tiros," "Nimbus," and "Aeros" permitted the weather forecasters to be immediately involved in the development of a universal system of weather forecasting.

Of course it is incorrect to consider that space observations will be able to completely replace surface meteorological service. The task of both is to, by supplementing each other, comprehensively expand and deepen the information necessary to a meteorologist.

Currently rational proportions are revealed in the distribution of "work" between the meteorological satellites and the surface weather services. At the same time exploration is underway of such forms and methods of observation of the weather parameters from space which could replace observations conducted on earth: sounding of the distribution of moisture content, temperature sounding through the entire thickness of the atmosphere, and evaluation of the condition of storm activity and the quantity of falling rain.

We will look at the general features that distinguish the normal synoptic map from satellite information.

The synoptic map contains data on the weather obtained from different meteorological stations located often at great distances from each other. On it the conventional signs are placed for the zones of cloud cover and position of fronts, the zones of precipitation and the centers of cyclones obtained by interpolation from individual observation of meteorological stations and ships.

The satellite information, as it is accepted to say, in the plane of the image provides continuous situations and details characteristic for the photo images.

Study of the photographs obtained from satellites on the structure of the cloud masses permits a revelation of the trajectory of movement of the air mass to which the cloud belongs, and can provide an idea on the pattern of winds at different altitudes.

A determination of the content of water vapor in the atmosphere and its variations provides important material for a detection of the thermal and water balance of the atmosphere, and the heat and moisture exchange between sea and dry land. Water vapors have a strong effect on atmospheric temperature. During evaporation accumulation of heat occurs which is accompanied by precipitation.

Satellite meteorology makes it possible from photographs of cloud cover to reveal the vertical stability of the atmosphere and the intensity of the vertical exchange of heat, which opens up the possibility of determining the condition of weather in the boundary layer of the atmosphere for a large number of parameters. The optic and radiometric methods of research from satellites make it possible to reliably distinguish the cloud cover from a snow cover, and consequently, trace not only changes in temperature of the underlying surfaces, but also changes in the snow cover of dry land, and ice covers of seas.

For observations of the cloud cover of earth, snow and ice formations a television apparatus is installed on satellites, with the help of which photographs are made in the visible and infrared sections of the spectrum. The photographs in the infrared rays can be made during the day and at night. At night they are the only source of information, but during the day they have unique information that differs from that obtained in the visible spectrum--these are data on the layers of clouds and their vertical development. In addition the fairly high sensitivity of the infrared gages makes it possible to find warm and cold air masses, and to evaluate the temperature field of the air masses.

Studies of the processes of weather formation using photographs from meteorological satellites have become an important means of finding storms and ice fields, and tracking the movement of storms over oceans where there are no meteorological stations. The pattern of wave action on oceans, like the visible structure of the cloud cover, provides specific information about the direction and velocity of wind in the lower layers of the atmosphere, and makes it possible to record zones of precipitation. It is true that interpretation of satellite photographs is complicated to a considerable measure by the fact that the brightness of the clouds is a complex function of a large number of factors.

The number of threatening elemental phenomena includes tropical storms. They are diverse in dimensions and intensity, therefore it is important to find and trace the direction of their development. With the help of the satellite "Tiros-5" in 1962 the evolution of a typhoon was successfully observed from the moment of its birth to its breakdown. The peculiarity of the condition of the cloud cover during the passage of the typhoon consists of the presence before the main system of clouds "of a prehurricane" line of squalls in the form of a band of convective cloudiness. The nucleus of the system of cloudiness of the typhoon was formed by dense cumulus low-lying clouds predisposed to changes when coming upon dry land. The photographs made it possible to find a link between the dimensions of the structure of the cloudiness and the maximum wind velocity, and in particular, to establish empirical dependences of the diameter of the cloudiness zone of the storm on the maximum wind velocity.

The tornadoes (strongest storms) observed in the United States and Australia are characterized by the presence of a so-called maternal cloud system, near which an extended offshoot is located. The tornado is often surrounded by a cloud mass. Bright zones of cloudiness up to 300 km in diameter are accumulations of rain clouds. The wind velocity in the tornado zone exceeds 100 m/s. One of the peculiarities of the distribution of cloudiness on earth is the spiral-shaped systems linked to large-scale cyclones. Photographs of these eddies can serve as a means of analyzing weather formation, since they bear features of a specific cyclone. Here one can find the presence of dry and moist air, and fix the position of zones separating the air masses. Successive photographing of the development of a cloud system in a cyclone makes it possible to trace it in dynamics and establish the moment the cold and warm fronts approach, and the moment of movement of the cold front into the zone of the warm front. And finally, one can analyze the stage of breakdown of the cyclone.

On a number of photographs of the cloud cover zones of clouds of a cellular structure are discovered, whose regular structure is governed, as is assumed, by the approximate stability in wind velocity as altitude increases. Such a zone of cellular cloudiness is located on the periphery of a major anticyclone.

The layer of clouds and fogs that form, for example, during the movement of moist air over the colder surface of the ocean in the coastal zone often are revealed on television images of the cloud cover obtained from satellites.

The results of research on the types of cloudiness are important. Small cloud elements visible from earth and serving to determine the type of cloud cover by the observer under normal condition often cannot be found on images obtained from a satellite. The field of small cumuli sometimes can seem to be a thin cover of layer clouds.

Vast bright cloud masses with diameter on the order of hundreds of kilometers are usually a thick layer of clouds. The regions of lower brightness in the shape of irregular spots often contain cumulus-rain clouds. The cloud masses with low brightness consist of cirrus, high-cumuli or cumuli of good weather.

Analysis of the meteorological information obtained from satellites shows that although the space photographs make it possible only to obtain maps of clouds and optically dense formations on the whole they provide an idea about many meteorological phenomena.

Thus the mentioned typhoons have characteristic cloud formations located usually at altitudes up to 12 km, therefore from them one can compile an opinion about the air currents at these altitudes. The altitude of the border of clouds is determined based on the spectral measurements of the outgoing radiation.

Although now weather forecasting is based on an analysis of the atmospheric pressure field from which fronts of air masses are determined, it is basically considered possible to base weather forecasting on observations of changes in cloud cover.

The meteorological satellites have already provided people with a lot of useful information. For example, in 1967 the satellite "Cosmos-144," included in the system "Meteor," found that the North Arctic Ocean from Wrangle Island to the Bering Gulf was practically free from ice; this permitted navigation to be started a month earlier than the usual period. With the help of the satellite "Tiros-2" in 1961 a typhoon was observed and predicted in the region of New Zealand. In the eastern section of the Mediterranean Sea jet streams occurring there were revealed.

In the regions of the Himalayas that are difficult to reach the scientists with the help of remote photographs establish the precise water pattern of rivers feeding the fields, cotton plantations and gardens. The obtained information made it possible to build irrigation structures with regard for the proposed influx of river water in the summer period.

Meteorological satellites have warned many times of the generation and direction of movement of major cyclones, as a result of which the residents of the coastal region were warned in advance of the threatening danger.

The photographs obtained by meteorological satellites for compilation of synoptic maps are being developed in a corresponding manner. In the United States, for example, two methods are used for the development. The first consists of developing the photographs directly at the reception station and projecting the obtained image onto a coordination grid. The configuration of the cloud cover is transferred to a standard synoptic map, where the experienced synoptic meteorologist preliminarily analyzes the images and selects the most valuable information. This method is used to obtain data characterizing the synoptic processes of a large scale, such as the position of a cyclone center. The second method consists of the construction of a geographical coordinate grid directly on the photograph.

Here distortions are considered that are introduced by the optic system of the wide-angle camera, and for each photograph an independent coordinate grid is constructed according to the orientation of the camera in relation to the local vertical.

In addition to information about the cloud cover of earth there is yet another complex of elements about which we receive data from meteorological satellites--this is information on the streams of radiation coming to the earth and given off by it. In particular, on a number of meteorological satellites the task was set of obtaining large-scale fields of radiation escaping into world space from the earth's surface and atmosphere which are in the field of vision of the receivers. Since the escaping radiation is determined by the reflecting and emitting properties of terrestrial objects, and by the nature of the air masses, then from an analysis of the temporal and spatial variations in radiation fields one in principle could compile an idea about the corresponding variations in the fields of meteorological elements, and make an analysis of the cloud cover that interacts with the corresponding air masses, and trace their movements in space and changes in time.

The results obtained on the radiation-thermal pattern of the system earth-atmosphere are used to develop a theory of climate and construct an atmospheric model.

The quantity of information transmitted by the meteorological satellite in turn alone can be compared with the information obtained from 15,000-20,000 surface stations. All of it must be processed before the beginning of the next turn. A session of information transmission begins upon command from earth or in accordance with the flight program. Information from orbit can be obtained directly, without being stored aboard, which is especially valuable for rapid weather forecasting. In the future the task will be set of obtaining "a space meteorological newspaper" at any time of day and even every hour.

How many satellites are required to guarantee such hourly information? It seems that everything depends on the orbit of the satellite. For example, if the satellites are launched onto an equatorial orbit, then to solve this problem it is sufficient to have two satellites with a 2-hour period of rotation and shift in phase by a half-period. In this case at any point of the equatorial belt one can obtain television photographs at hourly intervals. If simultaneously six to eight satellites are launched onto a polar orbit, then in the lower latitudes television photographs will be obtained at a rate of slightly less than an hour, while in the high latitudes there will be an overlapping in time and area. Here at six hour intervals world maps of the geographical distribution of data obtained from the satellites can be compiled.

According to other calculations the satellites should be put into orbit at altitude 500 km and with slope at an angle to the pole in direction to the west. By using a system of these satellites launched with a successive shift in time with such regard that they intersected all the latitudes at specific time intervals one can practically continuously trace the meteorological processes over the entire earth atmosphere.

Of definite importance can also be the project of a system made of three equatorial satellites that have a stationary orbit at altitude 35,870 km with period of rotation 24 h. In this case the satellites will revolve synchronously with earth, as if suspended over specific points of the equator. The value of the system consists also of the possibility of using it as a mail box where information can be concentrated from other meteorological satellites and then transmitted to surface points of information collection. The task in the future is outlined--to create a universal weather surface. This requires automation of all the measuring processes executed at the hydrometeorological stations and local weather bureaus. The fact is that many meteorological observations are made only visually, since there are no advanced instruments, and sometimes physical principles that permit automatic observations. This, for example, is recording of a number of atmospheric phenomena, shapes of clouds, and evaluation of the weather.

In the opinion of a number of specialists automatic hydrometeorological remote measuring systems must become the reference link in the complex automated system. One system will be able to encompass the region of 20,000 km^2, and free thousands of skilled specialists from heavy labor. Over the entire region of observations the primary measuring instruments will be arranged that make automatic measurements and transmit the obtained information to the hydrometeorological point.

System of Space Communication

The distance of radio wave spread depends on their length. Long waves can envelop the earth, although here they lose the greater part of their energy. Short waves guarantee considerably greater distance of radio communication as a consequence of multiple reflection from the layers of ionized gas located at low altitudes and the earth's surface. VHF waves are spread only within direct visibility. However precisely in this range of wavelengths the calmest operation in the ether is guaranteed. Here many radio stations can operate simultaneously on VHF without interfering with each other.

In the last decade the scientists and designers have developed a number of measures directed towards increasing the distance of radio and television communication; more advanced systems have been planned, the power of the transmitting and sensitivity of the reception stations have been increased, and a network of retransmitting lines has been set up. However continuous radio installation even of a medium-scale European country requires the creation of many dozens of transmitting stations linked by special cables. For our country that has an enormous territory and regions of difficult access this task is extremely complicated. For each line of cable or radio-relay communication that consists of a large number of intermediate retransmitting stations requires the installation of expensive transceiving apparatus, construction work, sources of power, and constant maintenance. For example, for the radio relay line Moscow-Vladivostok 150 surface retransmitters were needed, and for the cable line of the same length--over 1,000 amplification points.

Currently three main types of communication lines are used: main, of which a large number gather at a central point, from which along a common main channel communication occurs with other analogous points, where lines, again branching, are sent to the users; communication lines between the communication center and a moving object (ship, airplane, helicopter); communication lines between moving objects. The main mass of the so-called commercial communication whose number is constantly rising is implemented on lines of the first type. For example, whereas in 1969 the number of transatlantic two-way telephone communications between Europe and the United States was 2 million (345 channels) according to predictions for 1980 it remains to provide about 120 million communications, which requires up to 12,000 channels. The demand of the military services also rises for lines to guarantee coordination and functioning of army units.

It is known that one surface radio station can encompass with its "radio field" roughly 15,000 km^2. And if the retransmitting device is installed not on a mast, but on board a satellite, then one can create a communications system capable of encompassing the entire world.

The principle of the use of satellites to provide long-range radio communication consists of the fact that in the communication lines operating in the VHF range they fulfill the role of intermediate stations rebroadcasting radio signals from one surface station to another. As in the normal radio relay lines passive and active satellite rebroadcasting are distinguished.

In the first case the satellite is a simple reflector whose shell has, for example, the shape of a sphere (the American satellite rebroadcaster "Echo"). Passive rebroadcasting needs considerable power of the transmitting and high sensitivity of the reception stations, as well as low orbits of the satellite. Despite the evident advantages of such a retransmitter (high reliability and wide range) it is not considered promising. This will be discussed below.

In the second case on the satellite the signal received from earth is amplified and subsequently transmitted to another surface station. Active retransmitters can operate both with delay and without delay of communication. During the operation with delay of communication the satellite, flying over a point of data transmission receives and stores the obtained information, while above the point of reception upon command from earth transmits it. In this case the satellites can be launched to low orbits (on the order 300 km) and have considerable powers of the transmitting systems. However the small altitudes of the orbits limit the activity of the communication section to 2-3 minutes.

If operation occurs without delay of communication the satellite continuously transmits to the user the obtained information only at another frequency. Here communication will be carried out only in the case where the satellite simultaneously is visible from the sites of reception and transmission. Transmission without delay is possible also between more distant objects on earth through a system of satellite-retransmitters linked into a single chain. Retransmission with delay is used in the system "Kur'yer," while continuous--in the system "Molniya" and "Rele."

Passive retransmitters are divided into stabilized and unstabilized. The stabilized include flat reflectors, reflectors of on-board scattering, and short-circuited antennas. However stabilized passive retransmitters require the use of electronic control systems for the spatial position of the apparatus, which reduces to zero the main advantage of these systems--reliability and simplicity inherent to the passive reflectors. The unstabilized reflectors include sets of Luneberg lenses, V-reflectors, clouds of "needles," and metallic spheres.

Passive retransmitters are usually hollow spheres several tens of meters in diameter whose surface is covered with aluminum foil. For example, the American satellite "Echo-2" launched in 1964 was an inflatable sphere 41 m in diameter with a shell made of plastic film that had a mirror metallized coating. Later drafts for the satellites "Super Echo" were developed with diameter up to 300 m.

The main deficiency of passive satellite retransmitters is the great losses of energy of the reflected signal from the satellites with nondirectional radiation beam proportional to the fourth degree of distance; in active retransmitters the damping is subject to the law of second degree.

Comparison of the weights of passive and active reflectors that guarantee the same re-emission power per unit of active power shows that an increase in the dimensions of passive satellites to obtain greater amplification and power results in an impermissible increase in weight.

A comparison of the quantity of information that can be retransmitted in a unit of time also is not in favor of the passive systems. Thus with altitude of the orbit 1,000 km the rate of information transmission with regard for real limitations is 10^5 bit/s for a passive spherical satellite 30 m in diameter and 10^8 bit/s for an active satellite with power 1 W.

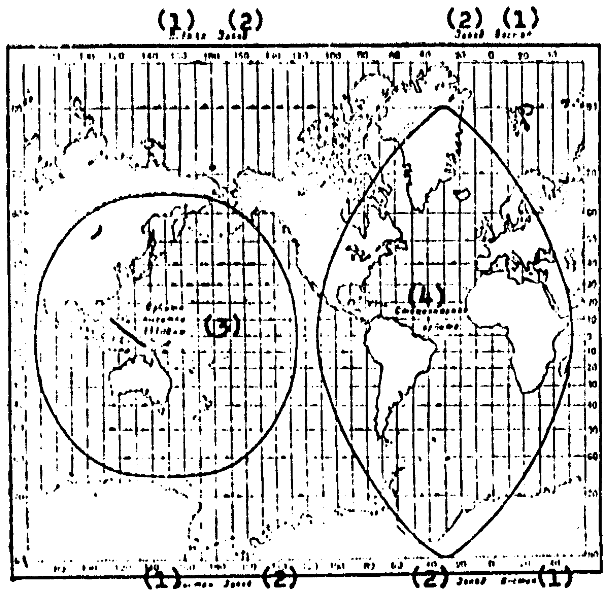
Determination of the specific orbit for a satellite retransmitter is an extremely complicated question linked to the selection of a number of other components and parameters of the system: the number and location of the surface points, the number of channels, limitations placed on the delay time of the signal, parameters of the booster rocket, and characteristics of the satellite and surface station.

Expansion of the communication zone by increasing the altitude of the satellite orbit is significant roughly to 8,000 km. Here circular orbits are more suitable from the viewpoint of the stability of the communication zone and the ratio signal/noise. An advantage of switching from an elliptical orbit to another--the satellite can have greater weight as compared to the satellite that is put into a circular orbit whose altitude equals the apogee of the elliptical orbit (with the same weights of the booster rockets). In addition on the elliptical orbits communication can be provided more economically between surface stations located in a limited range of latitudes.

Precisely on an elliptical orbit with parameters: perigee 497 km, apogee 39,380 km--the Soviet communications satellite "Molniya-1" was launched. The large amount of orbital eccentricity, the location of the apogee over the Northern, and the perigee over the Southern Hemispheres guaranteed communication sessions in the presence of one satellite between Moscow and Vladivostok to 9 hours with a total period of revolution 11 h 48 min. However the retransmitters with elliptical orbits also have significant deficiencies: it is necessary to alter the amplification of the on-board antenna as a consequence of the variability in distance to earth, and with perigees less than 370 km deceleration in the atmosphere results in instability of the orbit.

At what altitudes then is it expediant to launch the retransmitters?

It has been established that there exists a critical altitude on the order 9,250 km below which one can use nondirectional antennas and comparatively simple satellites. At great altitudes it is more expedient to use directional stabilized antennas, which reduces the required number of satellites that provide communication within the same region of the earth's surface.



Zones of Coverage of Earth's Surface by Communication Satellites Launched at Different Altitudes: left--by one of ten satellites from altitude 11,000 km, right--by one of stationary satellites (altitude 35,000 km)

Key:

1. East
2. West
3. Orbit with altitude 11,000, 100 km
4. Stationary orbit

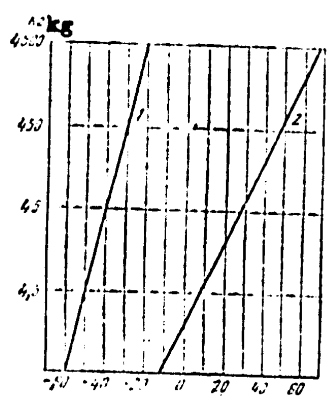
The selection of altitude of the orbit is affected by space conditions: x-ray radiation, gamma-rays, ultraviolet radiation, and high vacuum. Protection from radiations can be provided by the corresponding shielding. In particular, it has been computed that to shield from protons that have high energies thickness of the shield material on the order 25 cm is required, and this results in an impermissible rise in the weight of the entire satellite.

Currently altitudes less than 1,850 km are considered efficient for orbits of communication satellites for simple systems and intracontinental communication, and over 18,500 km for complex systems that provide intercontinental communication.

How many satellites are needed to maintain continuous communication between surface stations located, for example, 5,000 km from each other? It is considered that if the satellites are put into an orbit 1,500 km in altitude, there must be 400 of them, and with altitude of the orbit 8,000 km--40.

The most enticing is the idea of using stationary satellites for communication. A system made of three stationary satellites, uniformally distributed over the orbit can provide reception of radio and television transmission at any point of the earth, with the exception of the polar regions. A comparison of the zones of coverage of the systems made of ten satellites located at an orbit of 11,100 km, and systems of stationary satellites shows that in the latter system the zone of coverage is considerably greater. The retransmitting efficiency with the use of a stationary satellite does not depend on the location of the surface station, while at lower orbits it is reduced as the station is farther away from the equator. However such a communication system also has a number of significant shortcomings. They include: low reliability since the malfunction of one satellite disrupts the operation of the entire system; the need for great outputs of the transmitters located on the satellites; the need to use on the satellite a system of stabilization and orientation; the great required power of the rockets that put the satellite into orbit; and the considerable delay in the signal in time.

We will dwell in more detail on the last factor. There is a practical tolerance for delay time of telephone signals--in the telephone chain with one-way spread of the signal the delay must not exceed 0.25 s. With the use of double lines such a delay results in the appearance of an echo. In order to improve the quality of the signal in the long chains echo-barriers are used that interrupt the signal transmission in the time of reception, however the use of echo-barriers can result in interruptions or distortion of speech.



Dependence of Weight of AES on Emitted Power

Key:
1. Passive spherical reflector 2. Active AES
Along horizontal--re-emitted power in db relative to 1 W.

For a satellite on a stationary orbit the signal delay in time will reach 1.27 s, therefore its use for telephone communication is hardly expedient. More promising is the use of such a satellite for transmission of telegraph, phototelegraph and television signals.

Another important factor that determines the selection of the orbit is the time required for replacing the satellite in orbit. The sudden malfunction of apparatus can, for example, occur during the breakdown of the power sources, disruption in the functioning of the components of the electronic apparatus, or orientation system. In this case the time necessary to replace the satellite with orbital altitude 11,000 km is roughly 1.5 h, while for a satellite with stationary orbit it is three times greater. In addition it is necessary to consider that at low orbits the malfunction of one of the satellites when they are located in a ring results only in the decrease in the zone of continuous coverage or a short interruption in communication, the malfunction of a stationary AES (artificial earth satellite) will produce a long interruption in communication.

It is considered that communication lines that use satellites will become economically justified if the duration of trouble-free operation of the satellite will be several years. This factor makes strict requirements for reliability of the devices installed on the satellites. They must withstand mechanical and thermal impacts, operate under conditions of a vacuum and high radiation, and withstand acceleration to 15 g with vibrations with frequency up to 2,000 Hz. It is known that reliability can be improved by providing standby communication channels and apparatus, however this results in an increase in the weight, overall dimensions and input, which contradicts the limitations on these parameters placed by the characteristics of the booster rockets.

In the creation and operation of the satellite communication system the main cost is distributed between three elements: the satellites, the means of launching, and the stations. The cost of the satellites will be minimum if they are made in the form of small passive retransmitters, and the greatest for active retransmitters with stabilized directional antennas. In addition if the service life of the satellite is less than 1.5-2 years the main portion of the outlays for operation will be outlays for the replacement of a satellite.

The cost of the means of launching depends on the complexity of the launching method and the power of the rocket designed to launch the satellite. Thus according to foreign data the approximate cost of launching one simple nonstabilized satellite retransmitter is up to $5,000,000 and of a multiple-function retransmitter up to $10,000,000.

The main competitor for space communication on transoceanic lines is underwater cables, however a comparison of the cost of operation of these systems shows the advantage of the space system. In fact, outlays for the maintenance of a transoceanic line extending 5,500 km are roughly $27,000 for 1 television channel as compared to $10,000 in the system with a satellite.

The introduction of satellite retransmitters is currently following the path of using them for radio-telephone, phototelegraphic, and telegraph communication, as well as to transmit television programs.

The construction of a broad network of surface reception stations of space communication similar to the stations in the domestic system "Orbita" will make it possible for a space bridge to be one of the main forms of remote communication. The satellite communications system is suitable for rapid transmission of meteorological maps, and newspaper dies which permits the population of remote regions in our country to be supplied with central newspapers the day they come off the press.

A no less important role is space communication in television. Due to the system "Orbita" the programs of the central television have been made available to many millions of Soviet viewers. It would be impossible to create a similar network of program reception of central television in such remote regions of our country as the regions of the extreme north and the far east, and moreover in such a short time without using satellites. With the help of satellite communication direct television transmission is implemented between Europe, America and other regions of the world. In a few years, any major country will be able to transmit their radio and television programs to the entire planet. It is true that here the problem arises of the incompatibility of the television systems as a consequence of the difference in standard signals and types of receivers that exist in different countries. Thus, the standard number of lines in the television system in Austria, Belgium and the USSR--625, the United States--525, and England--405. There are differences in the modulation of the channel of sound accompaniment, for example in Austria, France, and the United States frequency modulation is used, in Belgium and England--amplitude. The overall width of the band in Austria--7, in France--14, and in England--5 MHz.

Promising results of the operation of experimental satellite communication systems have made it possible to set up a number of new tasks whose solution in the near future will provide a high-quality jump in the creation of a universal system of mass service.

The number of such tasks include, for example, maintenance of a surface command-measuring complex that guarantees flights of satellites and interplanetary automatic stations. The functioning of the system of satellite communication for these purposes will make it possible to abandon the branched network of airplane and ship tracking stations used today to communicate with the spacecraft. Experiments are underway to organize air traffic with the help of communication systems based on satellites with stationary orbits, whereby data on the coordinates of an airplane are sent from the airplane to the satellite and further retransmitted to the surface station for collection of data for their transmission to the central dispatchers point. Plans are being examined for the use of a communication system to collect information from meteorological satellites, meteorological balloons, and automatic weather stations, as well as from satellites designed to study the natural resources of earth and the secrets of the oceans. Apparatus is being developed for satellites that makes it possible to retransmit radio programs and television programs directly to the domestic receivers, by-passing the intermediate reception stations.

The question arises of creating satellite retransmitters on orbits around Mars, Venus and the moon which will make it possible to implement communication on the spacecraft with the earth at the moment they are located on the side of the planet not visible from earth. One of these plans provides for putting the communications satellite at the point of libration, at a distance on the order 65,000 km from the moon above its far side.

Navigation Through Space

Generally it is not very complicated to determine one's location while on dry land near reference points. It is considerably more complicated to do this while, for example, on an airplane in air or on a ship far from shores. It is necessary to consider that here the task consists not only of accurately determining the coordinates, but also laying a course that guarantees arrival at the point of destination.

At the same time the ever increasing velocities of airplane flight and the increasing distances of movement of ships advance higher requirements for the methods and means of navigation.

As far back as 15 years ago in the United States a decision was made to increase the accuracy of the means of ship navigation in the Navy, which should guarantee determination of the ship coordinates with error up to ± 2 miles in a time no greater than 10 minutes. In relation to submarines that are sailing in the submerged state for months the latter parameter acquires especial urgency.

The merchant marine has also developed definite requirements for the means of guaranteeing the navigational safety of ship sailing: the accuracy of their readings must not be less than 1% of the distance to a dangerous place during navigation in the ocean, and during movement in harbors--no less than 50 m with distance to the nearest dangerous point less than 3 miles.

During the movement of a ship its location is determined periodically. And in the intervals between these moments dead reckoning is implemented with regard for different factors--current velocity, wind velocity, waves. For dead reckoning graphic, analytical and automatic methods are employed respectively on graphs, formulas and tables, or calculators--dead reckoning analyzers. For any of the named methods the initial is information generated by the systems of course indication and measurement of the ship velocity.

The course is determined with the help of gyroscopic compasses, whose root-mean-square error in measurement is roughly 0.5°. Velocity is measured in logs; the relative error of their measurement is 1%. A deficiency of these instruments consists of the fact that they do not consider the meteorological factors in the measurement process. Systems based on measurement of the true movement of the apparatus--inertial systems are free of such errors. However they also suffer a serious deficiency--they are not capable of determining coordinates more accurately than those that were built into them. Today inertial systems are known that are capable of providing a root-mean-square error of coordinate storage of 0.1 mile/h. Therefore on lengthy marine voyages inertial systems must be periodically corrected.

As is known, since ancient times sailors have determined the position of the ship at sea or ocean with the help of stars or planets by astronomical methods.

This method is fairly reliable. But it can be used if the sky is not covered with clouds and the horizon is clearly visible, which does not occur that often. It is enough to say that in the northern latitudes of the Pacific Ocean the probability of cloudy weather (cloud cover over 8 points) is 40-80%.

In order to determine direction by a star goniometers are used--sextants, whose accuracy depends not so much on the perfection of the instrument as on the experience of the navigator. On the average it is 0.7'.

Radio engineering has provided the navigator with direction finding devices. The method of pinpointing location with their help consists of the simultaneous determination of direction on two transmitting radio stations, whose position is plotted on a map. The radio engineering devices make it possible to determine location with accuracy ±1% of the distance to the shore reference radio stations. And if this distance is 1,000 miles, then the error can reach 10 miles. However the action of a network of long-distance radio navigation encompasses mainly the coastal regions and directions of the main marine routes. At the same time a considerable portion of the ocean is outside the zone of their action.

Currently the means of navigation are employed in a complex that includes, in particular, three inertial navigation systems, radio sextants, an astronavigation periscope, electromagnetic log, course indicators, depth gages, and electronic computer. However even this complicated navigational complex cannot guarantee the required accuracy of navigation over the entire earth.

In the searches for more accurate methods of determining coordinates of moving objects the specialist turned to AES. Their use for navigational purposes is possible due to the natural rotation around earth, as a result of which at each moment in time one can with high accuracy indicate the position of a satellite relative to the earth's surface. Consequently, having determined the position of a moving object relative to the navigational satellite one can compute the position of the object in the earth's system of coordinates.

The main advantage of a navigational satellite system is the possibility of solving navigational problems under any meteorological conditions with fairly high accuracy. Such a system makes it possible to serve round-the-clock an unlimited number of users on a large area of the earth.

The satellite radio navigation system is a fairly complex set of equipment. It includes: several navigational satellites rotating around the earth according to assigned orbits and having on board special radio engineering equipment; on-board radio navigation stations installed on ships or airplanes to measure the navigational parameters and compute the geographical coordinates of the locations of these objects; a network of surface stations to control the parameters of satellite orbits; a computer center coordinating the work of the entire satellite navigational system and predicting the ephemeris (precomputation of coordinates) of satellites for the nearest time based on data of the control stations; time service that makes it possible to reckon time with accuracy up to 0.01 s and that issues time corrections; radio telemetric and communciation equipment to transmit commands and different information from earth to satellites and back in order to guarantee communication of the control points with a computer center.

The operating principle of the system is based on the use of satellites as reference points that make it possible to obtain the necessary direction finding information. If the satellite is in an orbit with known elements, then it is easy to compute its ephemeris. And by having a table of ephemerides, one can apparently compute also the coordinates of our object. However in fact it is much more complicated.

It is necessary to consider the change in the satellite orbits over time. The reasons for these phenomena could be sought in the off-centered nature of the earth's field of gravity (and consequently, the variability in the forces of gravity), in the effect of forces of resistance of the atmosphere, gravitation of planets, and so forth. Therefore the task of precomputing the position of the satellite with regard for the real disturbances is very voluminous.

There is a known technique for predicting the position of a satellite developed for the system "Transit" (United States). On the surface of the earth at a considerable distance from each other four radio stations for tracking satellites are placed, a computer center, a station for input of information to the satellites, and a time service. The tracking stations measure the parameters of satellite movement at that moment when it passes over them, makes corrections and transmits the information to the computer center. These data are used to determine the orbit, and then are transmitted to the input station. At the moment of appearance of the satellite in the zone of visibility of the second station the first sends to the satellite the necessary information and issues a command by which its working storage is freed of old data and it stores the new data. The correctness of the new input of the new data is controlled, after which the storage is disconnected for half a day, until the satellite enters the zone of action of the station. Further the satellite in accordance with the program will once in 2 minutes transmit information. The craft has a special inphase receiver where information after processing is printed on tape.

For a reliable determination of the location of a ship 2-minute intervals are sufficient. However the complexity of creating such a system is linked to the possibility of making a storage device with a large capacity of the memory--25,200 binary signs, whereby the accuracy of determining the coordinates is high (characterized by root-mean-square deviation of satellite coordinates--0.25 mile/day).

Currently the satellite navigational systems do not make it possible to continuously determine the coordinates of moving objects, since due to the earth's rotation around an axis at each point on the earth's surface the satellite can be observed only several times a day, and each time for a comparatively short time. If there are several satellites, for example four, the site of the moving object can be pinpointed every 2 hours.

In order to determine the coordinates of a ship in principle impulse, amplitude, phase and frequency methods of measurements can be used, on whose basis one can set up a number of radio navigational systems: angle-measuring, distance finding, Doppler, and combined. In order to use any of these methods of measurements on a navigational satellite it is necessary to have a transmitter that operates in a pattern of transmitter-retransmitter of inquiry signals. The oscillations emitted by them are received at the object (airplane or ship) and used to determine coordinates. At the same time the satellite ephemerides are transmitted to the object referring to the moments of navigational measurements. The ephemerides can, for example, be introduced periodically on a radio channel into a storage device of the satellite and be fed to its transmitter for additional modulation of the transmitter oscillations.

Angle-measuring method. On the satellite a transmitter is installed that generates continuous oscillations. With the help of the radio navigational station located on the airplane or ship by direction finding of the satellite transmitter its angular coordinates are defined (altitude, azimuth, or their derivatives).

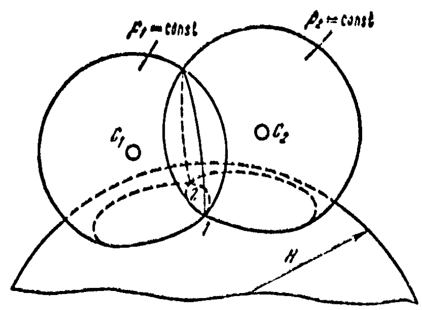
In determining the site of the object from angular altitudes the method of processing measuring results used in astronomy is employed. Measurements are difficult due to the great angular velocity of movement of the satellite in relation to the object of observation, and as a consequence of this the presence of considerable oblique shifting in the object--parallax. However here the rapid change in altitude of the azimuth of the satellite makes it possible roughly in 5 minutes to obtain more than 2 position lines.

In determining the site of the shift from the azimuths it is proposed to successively measure two azimuths on the satellite with a simultaneous accurate intersection of the measurement moments; the position of the craft is located as the point of intersection of two lines of equal azimuths.

Distance finding method. It is proposed that the observer can measure the inclination of distance to the satellite. The object to be coordinated fulfills the role of the inquiry station, while the radio engineering equipment of navigational satellite--the role of the transponder.

Having measured the distance at moment t_1, one can find the surface of possible position of object C_1 that is a sphere, in whose center the satellite is located at the moment of measurement (see Figure). The second surface of position C_2 can be determined having measured simultaneously the distance and up to the second navigational satellite, or to the same object, but at moment of time t_2. The third surface is determined simply, since the altitude of flight is known (for the airplane) h_{cam}, and consequently, the geocentric altitude computed from the center of earth, $H=R_3+h_{cam}$. By making from the center of earth a sphere with radius H we also will obtain this surface.

The three surfaces in intersection will provide two possible locations of the object: the true (1) and false (2), whereby the true is determined simply--it is too far apart from the false.



Scheme of Distance Finding Method of Determining Object Position from Two Satellites

Doppler method. The idea of the method consists of determining the relative satellite velocity. In the beginning when the satellite is at the horizon, the velocity of change in the distance is the maximum; at the moment when the line of sighting of the satellite is perpendicular to the vector of its relative velocity the change in distance is close to zero; it again rises to the maximum at the next moment in time.

Roughly the same pattern of change in the frequency parameter of the radio signal, like the change in distance can be obtained with the use of the widely known Doppler effect. Its essence is that with a change in the relative position of the transmitter and receiver the frequency of the signal received by the receiver differs from the frequency of the signal emitted by the transmitter by an amount called the Doppler shift in frequency.

By measuring the frequency of the signal received from the satellite one can determine the time when the Doppler shift of frequency equals zero. This will be at the moment when the observer enters the plane perpendicular to the vector of relative satellite velocity.

There is yet another method for determining the site of the object that is based on the use of satellites' stationary equatorial orbit when they can be viewed as immobile radio stars. If three satellites are put into a stationary orbit that are separated from each other by equal distances their totality will permit the navigator to determine the position of an object at any point in our planet, except the polar regions.

In this case it is not necessary to solve equations of satellite movement; it is sufficient to make a correction for the change in satellite coordinates as a consequence of the effect of external forces. The accuracy of determination of the observer's location, apparently, will be no worse than under the ordinary astronomical measurements, whereby the main methods of measurement can be the navigational methods--high altitude or distance-finding.

The navigational parameters of satellites can be obtained with optic, visual, radar, Doppler and photo-optical systems. Visual, optic and photo-optic systems have limited use according to the time of day, for example when the satellite is still illuminated by the sun, but the sky is already dusky. However the optic systems are more accurate than, for example, radio engineering making it possible to determine direction with error no worse than 5-10". The photo-optic systems can guarantee even greater accuracy.

Advantages of the radar system of observations of navigational satellites--their suitability for all weather and round-the-clock use, as well as rapid measurements. However the angular accuracy of the measurement of direction still does not exceed 30".

The United States has launched several experimental satellites whose goal is to verify the possibility of creating a navigational system, formulation of methods for observing satellites, and creation of navigational charts.

The first launching was unsuccessful--the satellite fell into the Atlantic Ocean. The second navigational satellite "Transit-1B" was launched in 1960. It was equipped with instruments for measuring navigational parameters, radio telemetric devices, apparatus guaranteeing tracking of the satellite, instruments for controlling on-board systems, and power supply source. The operating principle of the system "Transit" was based on the Doppler effect. In order to reduce the influence of the ionosphere on the accuracy of measurements the satellites were equipped with radio transmitters emitting four coherent frequencies. The satellite used one spherical antenna, with whose help both transmission of navigational and telemetric data, as well as reception of commands were carried out.

However the launching of the satellite "Transit-1B" was not as successful as expected. It did not go into the planned circular orbit with mean velocity 925 km. The real parameters of its elliptical orbit were: altitude of the perigee 375 km, apogee 754 km; as a result the time of existence of the satellite was reduced from 50 to 6 years. The satellite apparatus during the experiment operated satisfactorily, which made it possible to guarantee accuracy of the location determination on the average 0.5 km.

Experimental launchings of navigational satellites have shown, in the opinion of the American specialists, the possibility of creating a navigational satellite system on the Doppler principle. It has been established that for the middle and small latitudes a precise consideration of the effect of the ionosphere on the passage of radio waves is possible.

The main reason for errors in predicting the orbits of high-altitude satellites is the inaccurate knowledge of the earth's gravitational field. On the average errors in predicting the orbit a day in advance were 0.5 miles, while extrapolation of the orbits for 4 days produced an increase in error up to 3 miles.

A result of the formulation of the experimental variant in the system "Transit" should be the operating variant based on four satellites with circular orbits at altitudes about 1,000 km (this will make it possible to prolong their existence time up to 50 years and the radius of the zone of satellite observability up to 3,000 km).

The outlooks for a space navigational system are vast: it can use ships and submarines, large liners and vessels of the tanker fleet, and transoceanic airplanes. The use of this system will permit airplanes and ships to select efficient routes of tracking, reduce the outlays for search and rescue work, and can promote safe navigation.

According to the calculations given in the magazine AVIATION WEEK (United States) the data obtained from navigational satellites will permit a reduction in the length of transoceanic routes on the average by 45 minutes per day and guarantee an annual economic profit on the scales of the oceanic merchant marine of $130,000,000.

Chapter 8. Space--Arena for International Cooperation

Since in the course of space research problems are solved of a planetary scale, here as in no other area the importance of international cooperation is great. In this respect that fact is characteristic that the start of the space era falls within the International Geophysical Year--a measure that has no precedent in the past. Over 5,000 scientific stations, observatories and expeditions of many countries have conducted studies on different sections of the IGY program.

Further advances in the investigation of the near-earth space, the moon, planets of the solar system, and interplanetary space are inseparably linked to the expansion of the front of experimental work, perfection of the technique of space experiments, and the purposeful and systematic increase in the efforts of scientists in this area. As previously in the investigation of Antarctica, today in the investigation of space a stage begins of comprehensive and systematic studies in which especially great importance is given to the coordination of work of scientists of different countries, and closer international cooperation in the fulfillment of comprehensive lengthy scientific programs.

International cooperation in space research today is carried out on many channels. There are international organizations especially created for this purpose, bilateral and multilateral agreements have been concluded, international congresses and conferences of scientists are organized, and an exchange of scientific and technical literature is underway. One of the forms of scientific links is the collective visual and photographic observations of satellites implemented simultaneously from many countries.

Cooperation among scientists of the fraternal countries of socialist cooperation has acquired a broad nature. True to the principles of internationalism the Soviet Union generously shares its accumulated knowledge and experience in all fields of science and technology. This cooperation is spreading more and more to space science and technology as well.

At the meeting of the representatives of socialist countries in November 1965 the USSR proposed carrying out joint experiments with the help of Soviet satellites and geophysical rockets. The first such work was fulfilled on "Kosmos-261." Its main purpose--to investigate the nature of the aurora borealis. The processes which accompany these grandiose geophysical phenomena affect the upper atmosphere most strongly in the polar regions, but also touch the middle and even lower latitudes. Therefore it is very important to make simultaneous measurements from on board a satellite and on the surface geophysical observatories and stations operating on a single plan. The experiment on the satellite "Kosmos-261" was the first work of such type. Scientists of Bulgaria, Hungary, the GDR, Poland, Romania, the USSR and Czechoslovakia participate in it.

The Soviet Union has also proposed implementing launchings of satellites and geophysical rockets with apparatus developed and manufactured in the cooperating countries.

There were many difficulties on the path to creating the first international satellite. It was necessary to solve complex organizational, technical and scientific problems. In certain countries participating in the cooperation there was not enough experience and trained personnel. But nevertheless already within 2.5 years after the adoption of the agreed upon program the first satellite of the socialist countries, "Intercosmos-1" took up its scientific watch on orbit around the earth. It was designed to study the ultraviolet and x-ray radiations of the sun, and the influence of these emissions on the structure of the upper atmosphere of earth. Scientific instruments manufactured in the GDR, Soviet Union and Czechoslovakia were installed on board "Interkosmos-1." The scientists of Bulgaria, Hungary, Poland and Romania participated in the development of the scientific program and in the surface observations. One of the most significant results of this experiment was the finding of polarization of x-ray radiation of the sun. The studies of ultraviolet and x-ray solar radiation were then continued on a number of subsequent satellites "Intercosmos." With the help of "Intercosmos" measurements were made of the characteristics of the earth's ionosphere: concentration of electrons and positive ions, as well as the electron temperature near the satellite and the mean concentration of electrons between the satellite and the ground reception points. Scientists of a number of socialist countries participated in the formulation of a scientific program of these satellites and the technical requirements for the on-board scientific apparatus, as well as in carrying out the observations.

"Intercosmos" satellites have also been used to analyze the radiation situation in the near-earth space, study the link between the dynamic processes in the radiation belts of Earth with solar activity, and investigation of the nature and spectrum of low-frequency electromagnetic oscillations in the upper ionosphere.

The successive experiments on the satellites "Intercosmos" were promoted by the extensive ground astronomical and ionospheric observations carried out by many observatories and ionospheric stations of the socialist countries. The simultaneous use of telemetric information from satellites and data of ground measurements considerably enrich the picture of the studied processes.

In addition to the satellite studies program "Intercosmos" includes experiments carried out with the help of meteorological and geophysical rockets. Rocket studies supplement the satellite experiments, and at the same time have an independent importance. They make it possible to obtain the characteristic of a vertical atmospheric section, including altitudes not accessible for satellites. The data of rocket measurements can be easily linked in time and place.

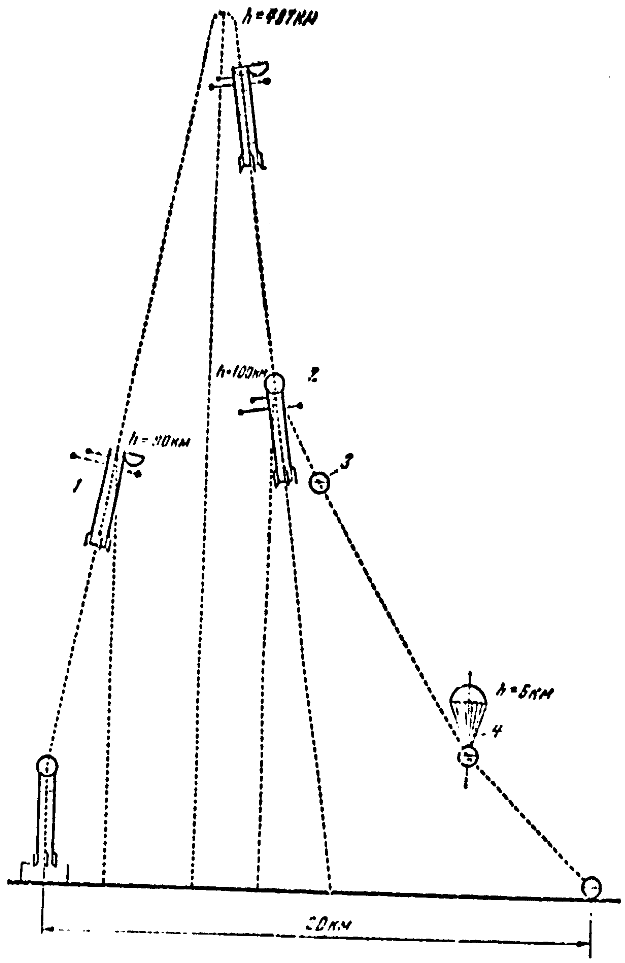
In order to conduct such experiments the Soviet Union has presented to its partners meteorological rockets, as well as a powerful geophysical rocket with lifting altitude about 500 km. The first rocket of such type--"Vertikal'-1"--was launched from the European section of the USSR on 28 November 1970. In the experiments conducted with its help, at all stages--from the creation of the apparatus to its testing, installation on the rocket and launching--the scientists of Bulgaria, Hungary, the GDR, Poland, the USSR and Czechoslovakia participated. The task of the launching included: measurement of a number of structural parameters in the ionosphere, investigation of solar radiation, study of physical and chemical properties of meteor particles.

Colleagues of four scientific research institutes of the USSR and six institutes of other socialist countries participated only in the development and manufacture of the scientific apparatus for this rocket. A railroad platform was required to deliver the ground unit manufactured in the GDR for the experiment that was designed to conduct the concomitant measurements of radio wave absorption. The total weight of the scientific and service apparatus on the rocket was about 1.3 T.

The successful experiments conducted on the program "Interkosmos" will be continued in future years on new satellites and research rockets. Here the complexity of the scientific tasks to be solved continually rises, and the jointly created apparatus is being perfected. New socialist countries and new collectives of scientists are being added to the work on direct measurements in space.

Besides direct measurements from on board the satellites and rockets the scientists find out many new things about the universe by using so-called indirect methods of observation. Among them optic observations of artificial earth satellites occupy a prominent place (visual, photographic, and photometric). Such observations make it possible to investigate atmospheric density at the altitude of the satellite's perigee, irregularity in the earth's gravitational field, to establish geodesic links at great distances and in difficult to reach regions, to conduct an ephemeris service that is necessary to predict the movement of satellites and control the operation of their scientific apparatus. Optic observations are an important means of tracking space objects on which the sources of energy have dried up.

The joint work of the scientists of the socialist countries on observations of artificial earth satellites and the use of these observations to solve scientific and practical problems began with the launching of the first Soviet satellite in 1957. Initially such work was carried out based on bilateral agreements. The accumulated experience permitted, starting in 1962, a transition to multilateral cooperation for observation of artificial satellites, which opened up the possibility of implementing more complex scientific research programs requiring the collective work of observers in many countries.



Flight pattern of rocket "Vertikal'-1"

Key:

1. Opening of cover of releasable container and extension of rod with scientific equipment sensors
2. Closing of cover and separation of releasable container
3. Free fall
4. Opening of parachute

An important element in the cooperation of socialist countries in the field of space physics is also joint observations carried out on astronomical radio-astronomical and geophysical observatories and stations, which creates the prerequisites for a successful carrying out of geophysical experiments on a planetary scale.

The cooperation of socialist countries is spread not only to the field of scientific research of outer space, but also includes the practical applications, for example in the operational weather service with the purpose of increasing the quality of forecasts.

In addition to the development of an intrastate system of communication through artificial earth satellites the Soviet Union is actively participating in the creation of an international system of space communication. When the active stations "Orbita" began to operate in February 1970 in Mongolia transmissions on the system "Orbita" went beyond the borders of the Soviet Union. Then a station was set up in Cuba. In a number of socialist countries scientific research and experimental design work is underway on a system of communication through artificial earth satellites "Intersputnik."

A good foundation for cooperation is the advances attained by the USSR scientists and other socialist countries in aviation and space biology and medicine, as well as in the related fields of sciences. The scientists of Bulgaria, Hungary, Poland, Romania, Czechoslovakia and the Soviet Union are conducting joint research on more than twenty topics. In the determination of these topics the traditional scientific directions of research institutions of individual countries were considered, their equipping with the necessary scientific apparatus, and the presence of trained personnel. Already the first specific results have been obtained in the fulfillment of joint work on the problems of space physiology, radiation safety of space flights, and pharmacochemical protection from ionizing radiation.

An investigation of the physical properties of outer space with the help of satellites and rockets, space meteorology, space communications, space biology and medicine--these are four of the main elements in the program "Intercosmos," four of the trends in cooperation with the socialist countries in investigating and developing outer space.

Over a number of years the successful cooperation has continued in the fulfillment of space experiments of Soviet and French specialists.

In October 1967 the first experiment took place that was provided for by a Franco-Soviet agreement. Apparatus developed by the French scientists for the formation of noctilucent clouds was installed on Soviet meteorological rockets. The experiment had the goal of measuring the temperature of the upper atmospheric layers. Observations during the experiment were carried out simultaneously from the earth's surface by a Soviet specialist, and from on board the airplane laboratory by French scientists.

The Soviet and French scientists are jointly investigating a complex of electromagnetic phenomena at magnetically-associated points of Earth located in the Northern and Southern Hemispheres. Both on the island of Kerguelen in the

Indian Ocean, and in the settlement of Sogra in the Arkhangel'skaya oblast the Soviet and French scientists are working together.

The French apparatus for the experiment to investigate solar radio emission in the meter range of radio waves (project "Stereo") has been installed on Soviet automatic stations in the series "Mars." Work has been carried out to create a radio interferometer with base Earth-moon. The French laser reflectors have reached the moon in Soviet spacecrafts. According to the program of Soviet-French cooperation in the field of studying outer space the satellite "Oreol" has been launched that is designed to investigate the upper atmosphere of Earth and the nature of the aurora borealis.

Within the framework of the Soviet-French program "Araks" an experiment has been carried out on sounding the magnetosphere by rapid electrons and on the formation of artificial aurora borealis.

The cooperation of Soviet scientists with scientists in the developing countries is evolving successfully; the developing countries are striving to their feasible contribution to outer space study. The Soviet Union is participating in works to prepare research on an international rocket site Khumba in India. The United States, France and other countries besides India and the Soviet Union are participating in these studies. Already for several years the Soviet meteorological rockets have regularly started from this test site. In May 1972 an agreement was signed between the USSR Academy of Sciences and the Indian organization to study space for cooperating in creating and launching the first Indian satellite. The satellite was designed by Indian scientists, it was manufactured at Indian enterprises, but a Soviet rocket put it into orbit in 1975.

In a number of countries of Asia and Africa with the help of the Soviet Union stations have been created and are being created for observation of artificial earth satellites and other space objects. Help in the organization of such stations and training of national personnel for their maintenance make it possible to include in the general work of investigating and developing outer space those countries which as yet cannot conduct independent studies on rockets and satellites.

The laboratories of many countries in the world have received for study samples of lunar soil sent to earth by Soviet automatic stations "Luna-16" and "Luna-20."

The necessary conditions are available for a realization of certain joint space programs between the scientists of the USSR and the United States. The foundation for Soviet-American cooperation in this region was laid by a special agreement concluded between the USSR Academy of Sciences and the United States National Aeronautics and Space Administration on 8 July 1962. Later, in October 1965 it was supplemented by an agreement on the preparation and setting up of joint work on space biology and medicine.*

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*The publication was issued in 1975 in three volumes--in the Soviet Union (in the publishing house Nauka) in Russian, and in the United States in English.

The scientists and specialists of both countries have agreed upon the implementation of cooperation in the first place in three directions: space meteorology, space communications, and study of the earth's magnetism.

In 1964 the first Soviet-American experiment was carried out in the field of space communications with the help of the American passive communications satellite "Echo-2." Through a direct communication channel established between the world meteorological centers in Moscow and Washington a regular transmission of meteorological information both ordinary, and that received from the satellites is being carried out. Soviet-American negotiations have taken place on questions of cooperation in the field of lunar cartography. An exchange has taken place of obtained samples of lunar soil. Extensive work has been carried out to prepare a Soviet-American space flight on a near-earth orbit with docking of the spacecraft.

The solution to the problem of docking of crafts in orbit is one of the most important advances of space technology of recent years. It is known that putting only 1 kilogram of weight into an orbit of an artificial satellite requires about 50 kg of starting weight of the booster rocket. One can imagine the weight that a rocket must have at starting that is designed to carry out a flight of man to planets in the solar system. It will be numbered in the hundreds of thousands of tons. Such booster rockets are unique designs that require a complex step-by-step working out under ground and flight conditions. Colossal starting structures are necessary for their launching. It is considerably more economical to assemble interplanetary craft necessary for man's flight to planets of the solar system from individual components put into orbit by comparatively low-power rocket boosters.

Expeditions to planets in the solar system are senseless without docking not only around Earth, but also around the destination planet, where apparently orbital base stations will be created. From them to the surface of the studied planet flights are made both by automatic probes, and crafts with crew which after the fulfillment of the research program begin to return to the orbital station. From this base crafts with cosmonauts will also blast off for earth. All of these operations are linked with the carrying out of approach and docking of spacecrafts in orbit.

The tomorrow of astronautics is the creation of large orbital scientific stations with lengthy existence. These stations will be set up also from individual blocks by their assembly in orbit. It will be necessary to provide continuous supply of the stations, replenishment of the fuel supplies, change of aggregates and apparatus with the help of transport craft. All of these operations of course require the multiple execution of operations of approach and docking in space.

And finally, the rendering of assistance to a spacecraft in trouble is senseless without the approach and docking with it of a craft that has come to its rescue. This can occur, for example, during the breakdown of equipment which guarantees the deceleration of the craft during descent from orbit and landing on Earth. However mutual assistance in space is practically impossible if the crafts are not equipped with the necessary means of search, approach and docking, and if one cannot switch from one craft to another.

The striving to create the technical foundation for a system of mutual help in space was one of the main reasons for the signing on 24 May 1972 between the Soviet Union and the United States of an agreement which, in particular, provides for the development of joint means of approach and docking of spacecrafts and stations. This agreement envisaged as the first experimental stage the implementation of docking and a joint flight of the Soviet spacecraft "Soyuz" and the American craft "Apollo" with the mutual switching of cosmonauts from one craft to another, which was successfully executed in 1975.

The signing of this agreement was preceded by a number of meetings of Soviet and American specialists (they began in 1970) at which principles of cooperation between the Soviet Union and the United States in solving technical problems linked to docking of crafts and stations were worked out. For work on different aspects of this program several working groups were set up which met many times to discuss the principles and specific proposals for the creation of joint systems that would permit docking and transition from craft to craft.

Since the very beginning it was evident that the task of preparing the crafts "Soyuz" and "Apollo" for the implementation of the program approach, docking, joint flight and transition of cosmonauts from craft to craft was very complicated and its solution required great efforts by both the Soviet and the American sides. The fact is that there were no contacts between the developers of the spacecrafts. The designs were based on different principles since at that time neither side had docking in mind.

In order for each craft if necessary to approach and dock with any other craft it is necessary to carry out three main conditions: compatibility of the docking aggregates, i.e. all devices which directly adjoin during docking; compatibility of the resources that guarantee the searching and approaching of the crafts; and compatibility of the parameters of the atmosphere in the craft, in particular its composition and pressure.

In addition to the compatibility of the docking aggregates the design and automatics of each of them had to be universal, active-passive or, as it is now customary to say, androgynous. In other words, each docking aggregate must execute all the necessary functions both on the active craft, and on the passive: for any craft can be in the position of expecting help and in the role of coming to assist.

The extant designs of Soviet and American docking aggregates differed so much that mutual docking was completely excluded. Moreover, the joint development of a design of docking aggregates showed that none of them could be used as the foundation for creating a new universal aggregate. This is primarily because on "Soyuz" and on "Apollo" the docking assemblies were made on the scheme "pin-cone" (pin with clamp on the active craft and reception cone on the passive).

The Soviet and American specialists had to develop a design of a completely new, completely compatible androgynous docking aggregate with peripheral arrangement of the locks which could be used on both "Soyuz" and on "Apollo." In 1972 models of this aggregate passed laboratory testing.

The compatibility of the resources guaranteeing the search and approach of the crafts was a no less complicated task. The active craft, using radio engineering or optic resources had to find (of course, with the help of ground services) the passive craft and approach it.

The main-engines system of the active craft makes it possible for it to maneuver, by changing all six coordinates of its position (three coordinates of the center of mass and three angles) and the corresponding components of velocity. As a result of the maneuver the active craft must approach the passive with assigned accuracy for all the relative parameters of velocity and mutual position in space, and guarantee in the final analysis mechanical contact on the docking aggregates of both crafts.

As a rule, the passive craft with the help of its radio system assists the active craft in carrying out the search and approach. In certain cases the passive craft executes a limited maneuver upon command from Earth or from the active craft. But it can also happen that a craft in trouble will not have the possibility of maneuvering. In the orbital system of coordinates it will in this case be simply a body occupying a random position in space.

During the search and approach the radio systems of both crafts operate jointly. For this they must be constructed on the same principles, use single methods of measuring parameters of relative movement, the same type of modulation, matched frequencies, power of the transmitters, sensitivity of the receivers, and beam pattern of the antennas and other characteristics.

In order to determine the relative position and parameters of mutual movement of space objects each of the craft, both "Soyuz" and "Apollo" have their own radio systems. Their characteristics, including the characteristics of the information used significantly differ. In the joint experimental flight it was decided to implement the search and measurement of parameters of relative movement (radial velocity and distance) with the help of the radio system of "Apollo" which acted as the active craft. On "Soyuz" the reciprocal part of the radio system of "Apollo"--the transponder was installed. During approach of the crafts the optic system was also used with the help of which "Apollo" could observe "Soyuz" from a distance of several hundreds of kilometers, as well as determine the angular position of the sighting line. For optic measurements in darkness (from a distance of several tens of kilometers) impulse light beacons were installed on "Soyuz." On the final segment of approach the precise mutual position of the crafts was determined visually.

All the measuring information entered the on-board computer which made recommendations necessary for controlling the craft.

As for the third condition of compatibility, the matching of atmospheric parameters of the crafts, it does not require especial explanation. It is quite evident that even after the crafts dock the cosmonauts do not transfer from one to the other if there are significantly different atmospheres in the crafts. On "Soyuz" the atmosphere was practically analogous to the earth's atmosphere which we are accustomed: pressure 760 mmHg, content of oxygen 17-33%, nitrogen 82-66%. "Apollo" used atmosphere with 100% content of oxygen and pressure 260 mmHg. Such a difference in atmospheres did not permit the transitional hatches to be opened after docking of the crafts and communication between the living compartments. It was also impossible to have rapid transition of the crew members from one craft to another.

It was also impossible to unite the atmosphere of "Soyuz" and "Apollo" also because the air conditioning systems on these crafts were constructed on completely different principles. Continuous regeneration of atmosphere occurs in "Soyuz"--special devices absorb carbon dioxide and release pure oxygen by breakdown of alkaline metals. The intensity of this process is controlled by automatic devices regulating the atmospheric composition. On "Apollo" carbon dioxide is absorbed by nonrecoverable absorbers, while the necessary content of oxygen is maintained by the on-board supply in cylinders. Unification of the atmosphere of the crafts with such different systems of air conditioning would have resulted in a disorder in the automatics of these systems, and disruption of their normal operation.

For the joint flight "Soyuz"-"Apollo" creation of a transitional (docking) module was provided with a unique lock-gate chamber which after docking was arranged between the manned compartments of the crafts on the path of the cosmonauts from one craft to another.

The transitional module was a component part (compartment) of the craft "Apollo" and it was put into orbit together with it. In order to switch, for example, from "Soyuz" to "Apollo" the cosmonaut had to open the trap door in the transitional module in which by this time the atmosphere had been created corresponding to the atmosphere of "Soyuz", enter the module, close behind him the trap door and pass through the process of desaturation. The pressure in the transitional module was gradually reduced, the percentage content of oxygen was increased. By the end of desaturation in the transitional module a purely oxygen medium had been established with pressure 260 mmHg. The cosmonaut was prepared to transfer to "Apollo."

The reverse passage also occurred through the lock-gate chamber "transitional module" and was accompanied by a gradual change in the parameters of its atmosphere.

As already noted, desaturation is a lengthy process, and essentially, excludes the rapid transition from craft to craft. One can do without desaturation and radically solve the problem of transfer only by bringing the parameters of the atmosphere in the crafts close together, for example by reducing the nominal pressure in the compartments of "Soyuz." The fact is that in the transfer of the cosmonaut to a purely oxygen medium with pressure 260 mmHg the nitrogen dissolved in his organism with pressure no greater than 500 mmHg does not present a danger. In this case one can abandon the process of desaturation. Such a variant, although it is linked to a number of difficulties and inconveniences, was adopted for the joint flight of the crafts "Soyuz" and "Apollo" as the main variant.

The joint flight of "Soyuz" and "Apollo" also required extensive work in relation to flight control. It has its own problems of compatibility--technical and organizational.

The joint flight, mutual maneuver, approach and docking of the crafts was impossible without reliable radio communication between them, and communication with the ground tracking points. In order to guarantee such communication on "Soyuz" and "Apollo" additional radio systems were installed operating on frequencies accepted both by the Soviet and by the American side. Reliable multichannel communication and a precise interaction of the Soviet and American ground command measuring resources and light control centers were also required.

The Soviet and American specialists jointly developed a detailed flight program. The important task was also the special preparation of the crews, their training, familiarity with individual components of equipment of the other craft, study by Soviet cosmonauts of English, and American of Russian.

The program of scientific experiments on board the spacecrafts "Soyuz" and "Apollo" provided for both independent and joint studies. In 1973 at the March and July meetings of Soviet and American specialists five joint scientific experiments were approved.

The experiment "ultraviolet absorption" was proposed by the American scientists and designed to measure the concentration of atomic oxygen and nitrogen in outer space at the altitude of the flight of the crafts. The scientists of the Institute of Space Research of the USSR Academy of Sciences participated in the development of a technique for carrying it out. The apparatus was manufactured in the United States.

The essence of the experiment consisted of the fact that on one spacecraft a source of radiation was installed in the reception apparatus, and on the other--V-reflectors. By recording the changes in intensity of radiation on the path from one craft to another and back one can draw conculsions about the composition and temperature of the atmosphere at the flight altitude. Carrying out the experiment required fairly complex maneuvering in orbit and was started after the final separation of the crafts.

It should be noted that a reliable determination of density of atmospheric oxygen and nitrogen is completely necessary for a deeper knowledge of the physics of the earth's atmosphere. Until recently the main tool for the study of the chemical composition in the upper atmosphere was mass-spectrometers of different types. However the flight of the spacecraft in the upper atmosphere is accompanied by the release from its surface of gas particles. Its own "atmosphere" is formed around the craft. Its density can be altered depending on the intensity of solar illumination, light altitude, and so forth. At the same time it is difficult to consider such changes, and they result in errors in atmospheric parameter measurements with the help of mass-spectrometers. With the use of the method of ultraviolet absorption the influence of the "atmosphere" of the craft can be completely excluded. The experiment "ultraviolet absorption" also permitted a comparison of the findings with results of already made mass-spectrometer measurements.

The second experiment--"artificial solar eclipse" was proposed by the scientists of the Institute of Terrestrial Magnetism, Ionosphere and Radiowave

Propagation of the USSR Academy of Sciences. The experiment could be carried out only with the participation of both crafts during their joint flight. The spacecraft "Apollo" that had a round cross section took upon itself the role of the moon, while the eclipse was photographed from on board "Soyuz." Of decisive importance in the experiment was the precise calculation of the movement and matched movements of the crews carrying out the maneuvers.

In addition to an observation of the corona the experiment included photographing the "atmosphere" around the "Apollo" craft. On board "Soyuz" a search was also carried out for coronal rays on the nocturnal sky when the sun was slightly below the horizon.

Two experiments were associated with biological problems. One of them studied the so-called zone-forming fungi--a special species of mold that does not require for development any special condition and nutrient medium. The fungi multiply with the help of unique ring spores, whereby everyday one fungus throws out one ring. The experiment was set up in order to investigate the problem of genetic changes, as well as the influence of radiation on living organisms. To carry out this experiment the Soviet scientists developed a special instrument "Ritm-1."

The other biological experiment, "microbial exchange," had the task of evaluating the nature of natural exchange of microorganisms under conditions of a space flight between crew members and between the crews of different crafts. The findings are being used to formulate recommendations for the prevention of human diseases in long space flights.

And finally the last group of joint experiments was linked to an investigation of the influence of weightlessness on the processes of melting and crystallization of different materials. The experiments were proposed by the American scientists and united under the general conditional name "universal furnace." The Soviet portion of the scientific program of these studies was developed in the Institute of Metallurgy of the USSR Academy of Sciences.

The "universal furnace" was installed in the docking module of the "Apollo" craft, while the samples for testing were placed on the craft "Soyuz." To study the effect of weightlessness on the process of melting a mixture of metals with different specific characteristics aluminum was selected containing tungsten globules arranged in a certain manner. The mixture was heated under conditions of weightlessness up to 1,100°. The goal of the experiment was to investigate the basic possibility of creating by metallurgical means under conditions of weightlessness composite materials with previously formed structure from elements with significantly different weights. Under terrestrial conditions the process is impossible.

The obtaining of monocrystals of semiconductors made of liquid melt was investigated with the example of germanium containing 20% silicon by weight. The process of sphere-formation under conditions of weightlessness was studied on the example of melting aluminum powder.

The experiment "universal furnace" laid the foundations for production in the future of monocrystals in orbital space stations. The initial materials will be manufactured on Earth and sent into space, while the finished items will be sent back to Earth.

Already during the flight of the craft "Apollo" a decision was adopted to conduct yet another joint scientific experiment. For the first time in world practice in space research observations were made of x-ray sources from on board two manned apparatus. "Apollo" had an x-ray telescope analogous to the telescope "Filin" installed on the station "Salyut-4." Simultaneous observations or those close in time make it possible to carry out a mutual comparison of measurements, analyze the stream of radiation with different temporal scale, and exclude the effect of systematic errors in instruments.

Thus, whereas at the first stage the cooperation of the USSR and the United States in space research was limited mainly to an exchange and discussion of findings, the comparison of techniques, and at best, coordination of certain plans, the joint flight of "Soyuz" and "Apollo" made the first step towards "compatibility" of the programs of two space powers in the direct sense of the word. It designates a qualitatively new stage in the development of astronautics that is of great importance for its future.

A considerable number of public and intergovernmental organizations are currently involved with the questions of investigating and using space in a certain plan. In the family of so-called specialized institutions of the United Nations alone the problems of developing space are of interest to the International Union of Telecommunication, the World Meteorological Organization, United Nations Organization on Education, Science and Culture, the World Health Organization, the International Organization of Civil Aviation, and others. Among the public scientific organizations questions of space research have a direct relationship to the activity of a number of scientific unions and committees that are united by the International Council of Scientific Unions. The Association and Institute of International Law have made their contribution to the formulation of legal aspects of space development.

These and many other organizations contribute to the development of international cooperation in the study and use of outer space. In addition to them there is a small group of organizations that has been especially set up to coordinate, regulate or implement international and national programs for the investigation and development of outer space. They include the Committee on Space Research, COSPAR. It was established on the initiative of the International Council of Scientific Unions in October 1958 in order to continue cooperation in investigating upper layers of the atmosphere in space that was formed in the period of International Geophysical Year. The committee unites the leading scientific institutions of over 35 countries and 10 international scientific unions, whose activity is linked to space research.

Among the intergovernmental organizations involved in space problems a leading place belongs to the United Nations Committee on the Use of Outer Space for Peaceful Purposes. The committee which includes 37 states is a center for cooperation in the peaceful use of outer space. The Soviet Union has made its constructive proposals on all questions discussed in the committee.

In the course of recent years considerable progress has been attained on the path of international cooperation on legal questions of developing space. On 10 October 1967 an agreement was signed on the principles of activity of states to research and use outer space, including the moon and other celestial bodies. Starting on 3 December 1968 the second international agreement on space acquired the force of an international law--the agreement on rescue of cosmonauts, the return of cosmonauts and return of objects launched into outer space.

The main significance of these documents adopted on the initiative of the Soviet Union consists of the creation of such a legal order in space which to the maximum degree would promote the development of broad and equitable cooperation of states in the study and use of outer space for peaceful purposes.

"Space must become the arena of scientific research, international cooperation, and not the arena of hostile conflicts," these words, expressed by L. I. Brezhnev at the meeting in honor of the heroic flight of the cosmonaut G. T. Beregovoy expressed the essence of the Soviet Union's policy in the field of space development.

Having been the first to lay the stellar road for mankind the Soviet Union places its achievements in research and the use of outer space for the service of peace and international cooperation.

Chapter 9. Outlook for Space Research*

Currently space research is entering a new phase. It is becoming a normal type of scientific research activity, while space is becoming a work site, and a laboratory for scientists. After the first, one can say, reconnaissance experiments an era began of systematic research, while the future decades will undoubtedly be marked by even greater advances. In future years the main problems of researching the near-earth space will remain further investigation of the earth's upper atmosphere, magnetosphere, and solar-terrestrial bonds. We are only approaching an understanding of such phenomena of nature as aurora borealis, magnetic storms, and the radiation belts of Earth. The only way to guess the mechanism for their occurrence--setting up of comprehensive experiments on Earth and in space, and the simultaneous study of these phenomena as a whole.

Works on geophysics are gradually outgrowing the framework of near-earth outer space and going into the interplanetary medium. Investigation of the processes occurring there is extremely necessary for a more detailed explanation of solar-earth bonds and determination of the effect of the sun on Earth. These problems will be solved based on large automatic stations that carry a complicated set of instruments.

*The predictions and projects discussed in this chapter have been published in Soviet and foreign press at different times.

Besides the passive, purely measuring methods an ever greater role will be played by active experiments in space--active intrusion in the processes occurring in the space medium, with the help of sources of plasma, electron and ion beams. Such experiments will make it possible, in particular, to verify many hypotheses on the structure of the magnetosphere and the behavior of particles in it, the mechanism for formation of aurora borealis, and in the final analysis--raising of the question of the controlled effect on the near-earth space.

The further development of extra atmospheric studies of the sun in the x-ray, ultraviolet, infrared, submillimeter and radio ranges of the spectrum is planned, and specialized solar satellites will be created.

The studies of solar physics are associated not only with the fact that the processes on our star determine the physical condition of the interplanetary medium, atmosphere of planets and life on Earth. The sun is the closest star to us and supplies information on the processes in the stars. Investigation of the sun makes it possible to explain questions of the transformation and transmission of energy from a central source into the photosphere and further; the origin, evolution and distribution of the solar magnetic field; nature of differential rotation, solar activity, and high-energy phenomena on the sun; chemical composition and nature of the photosphere, chromosphere and corona.

The further development of research of the moon, Venus, and Mars based on rocket space technology will be continued. Ahead lies the massive creation of resources for studying planets, their surfaces, interior of the atmosphere, radiation and magnetic fields.

The accumulated experience of space research indicates that the broad circle of scientific problems, primarily problems associated with investigation of the moon and planets can also be solved with the help of automatic machines. A promising direction is the realization of plans for studying planets by automatic machines that possess a high degree of autonomy during movement over the surface of the celestial bodies, and the ability to perceive the environment, analyze it and make decisions on further actions depending on the situation. The creation of such automatic resources is linked to solution of the problems united by the concepts of artificial intellect and integrated robots.

Nevertheless the direct participation of man in the experiments on board spacecrafts is a necessary factor of space research and the future in space belongs precisely to man. Automatic machines lay the path for him. The flight of Yu. A. Gagarin marked one of the greatest conquests of human thought of the 20th century. After "Vostok" newer and newer spacecrafts were launched. People have already been even on the moon. As a result of all these flights it was proved that man can live and work in space, and carry out planetary voyages. One of the next problems on this path will apparently be the creation of long-term orbital space laboratories.

What horizons are opened up by the creation of a large scientific complex on a near-earth orbit? What does the solution to this problem provide mankind?

First of all the national economic importance of orbital stations is inestimable. We have already spoken of the problems that can be solved with their help. One can name such problems as mapping of the earth's surface. As of now almost half of the territory of our planet (according to the data of UNESCO, about 40%) does not have detailed maps. The topographers of orbital stations will be able with high accuracy to establish the coordinates of very distant points, pinpoint the position of objects on aerial photographs, and determine the coordinates of islands, reefs and shallows. By serving enormous sections of the planet they can significantly accelerate the mapping of regions of difficult access.

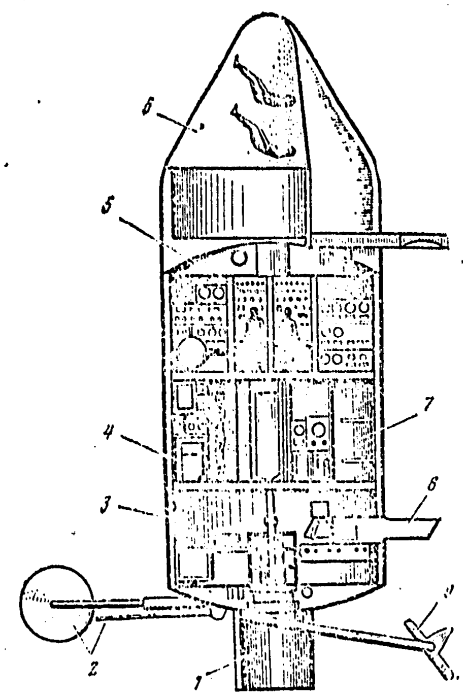
Orbital laboratories will render an invaluable service also in the study of natural resources of the planet. Investigation of the composition of the terrestrial crust, the nonuniformities in its mass, examination of gravitational and magnetic anomalies from on board orbital space stations will help to reveal previously unknown deposits of minerals.

From orbit one can study the water resources of Earth. On photographs obtained from space snow and ice covers are clearly visible. Determination of the correlation of territories free from snow and covered with snow is of especial interest for predicting floods, makes it possible to determine the floodplains and river deltas that can be filled with water, and major basins with stagnant and running water. Analysis of photographs makes it possible to establish the region of exit of underground waters to the surface, the salinity of soils, and their erosion. And all of this on the scale of entire countries. The world hydrological service created on the basis of orbital stations will make it possible to obtain exhaustive ideas on the water resources of our planet and formulate scientific recommendations for their expenditure.

Scientific laboratories in orbits will permit a considerable expansion in the research work to investigate the near-earth outer space. The magnetic field of earth will become a constant object of study, which will promote an increase in the accuracy of navigation, and a solution to navigational problems in aviation. Magnetometric apparatus installed on board of such stations will permit magnetic photographing much more rapidly than by surface methods, and over a considerably greater portion of the earth's surface.

Biological laboratories will also appear on orbital space stations. The biologists will be able to conduct extensive basic research on the effect of a lengthy stay in weightlessness on living organisms, and investigate questions linked to man's adaptability to unusual conditions of space flight. No less important is the problem of the existence of life outside Earth. Its solution, possibly, will be helped by studies of the microbial content of the upper layers of the atmosphere, and chemical analysis of meteors.

The figure (p 64) presents one of the many published plans for an orbital station made as a cylinder with two walls. Such a design follows from the requirements of thermal, anti-radiation and anti-meteor protection. The outer screen is made of beryllium, while the inner wall is aluminum. Within the cylinder there are research laboratories and a control center. The design provides for outer chambers for conducting research directly in the space medium.



Plan of Orbital Station of Rigid Design for Conducting Geophysical, Astronomical and Medical-Biological Studies

Key:
1. Space laboratories
2. Antenna
3. Astronomical and geophysical laboratory
4. Biochemical laboratory
5. Control center
6. Rocket apparatus
7. Medical laboratory
8. Telescope
9. Telescopic reflector

The crews of the orbital stations will conduct a number of studies of an industrial nature, since scientists assume that many production processes can be carried out much more easily in space than on earth. Thus the force of gravity under terrestrial conditions promotes the settling of heavy components in solidifying liquids, while light components remain on the surface. It is possible that under conditions of weightlessness such liquids will be cooled and hardened with an equal degree of density. Such objects as ball bearings, lenses, mirrors and many others will be produced in space with such accuracy that is impossible under terrestrial conditions. The advantages in the quality and energy saving, for example, in the production of ball bearings under space conditions, their strength and durability completely justifies the outlays for the creation of an "orbital plant." The electrostatic fields, capillary forces and forces of surface tension can become instruments in the treatment of cast objects in space. Enormous outlooks are opened for the optic industry, in particular in the production of large-high quality lenses, of especial importance for astronomists.

It is evident that in the future on the near-earth orbital stations unique astronomical observatories will be set up. The astrophysicists will also obtain excellent potentialities for their studies.

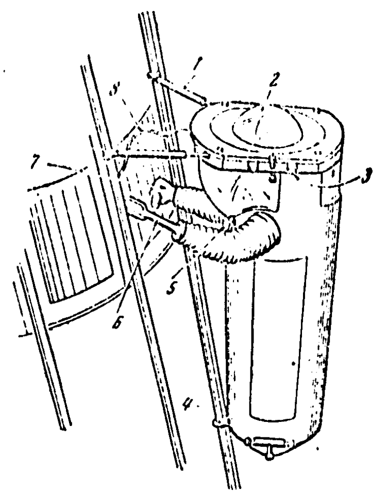
One can imagine a relatively inexpensive space astronomical observatory with two large telescopes. The station itself will be the second stage in the two-stage rocket. During the putting into orbit the second stage, equipped with one liquid-propellant rocket engine will be a tank for fuel within which all the mechanisms of control and different equipment will be placed in a special compartment. In the nose section there will be a capsule with the crew of the station. Subsequently the capsule will become the means for returning to Earth. At the moment of putting into orbit the tanks of the station are filled with fuel and the crew is located in the capsule. After going into orbit the tanks are purged by a stream of nitrogen. Simultaneously a multiple change occurs in the orientation of the rocket to heat the tank by solar rays. Then one of the crew members, passing into the central compartment from the capsule wearing a spacesuit hermetically seals the tank and opens the trap doors for the equipment compartments. After checking with nitrogen the hermetic sealing the tank is filled with air and the remaining crew members enter it. The central compartment is transferred to a working condition, and then the shields of the nose cone are opened on whose inner surface the solar batteries are located. The station receives current. One of the crew members in a spacesuit goes outside and assembles the external equipment.

For the creation of large orbital space stations it is evidently necessary to use assembly in orbit of individual components previously supplied there. Assembly in orbit will significantly draw near the periods for creating large stations. Their assembly directly in orbit of sections and blocks supplied from Earth will make it possible to obtain a design that is more adapted to orbital conditions. In this case it will not be necessary to calculate the design of the station for those considerable aerodynamic, inertial, and thermal loads that accompany the launching and flight on the active segment of the trajectory. If the station will be put into orbit directly from Earth, these loads result in a heavier design, although the duration of their action will comprise a negligible fraction of the total existence time of the station in orbit. If necessary one will be able to adjust the assembled station in accordance with the changing scientific and technical tasks.

The orbital stations will be made up of the most diverse assembly units, for example from housings of the last stages of the rocket boosters or special model sections from which can assemble stations of different target purpose. Each section can be, for example, a laboratory of specific purpose or a living compartment, and have equipment which after assembly of the station becomes a component part of the general system of energy supply and life support of the crew. The most expedient is the geometrical shape of a model station--sphere or cylinder. The sections of such shape have the least weight with the assigned useful volume. They are convenient to assemble and fit well into the contour of the rocket boosters. The station that is assembled from cylindrical and spherical blocks can have a different configuration.

The model construction in space will make it possible to reduce the time necessary for the assembly of orbital stations, and mechanize to the maximum the assembly operations.

For outside work the cosmonaut-assembler will have spacesuits with autonomous life support system. In order to preserve the specific position in space it will be necessary to equip the cosmonaut with a stabilization system. It will include sensitive elements, for example gyroscopes, and executive organs--minature jet engines. For movement outside the station the cosmonaut-assembler will have to have individual means of advance: waist miniature engines, jet pistols, and so forth.



Assembly Capsule

Key:

1. Mounting stabilizer
2. Trap door
3. Maneuver jets
4. Outer rail
5. Illuminator
6. Special surveying tool
7. Surveying glove
8. Power cable, communication and air hose

However, lengthy work outside the station still presents considerable difficulties for the cosmonauts. Weightlessness, for example, will impair the execution of many, even the most elementary operations of assembly. Neither a puller, nor tools with the minimum torque and the weakest impact energy will help here--one approach to error can repulse the cosmonaut a considerable distance from the craft.

Perhaps, it will be necessary to completely abandon threaded connections in the docking assemblies of the sectional design, having replaced them with welding, or develop special adaptations for welding which would exclude the necessity of rotational movements, for example a tool that has a zero torque.

Certain designers propose using in the work of the cosmonaut on the external surface of the craft a special outfit in the form of a tripod whose upper section encompasses the back of the cosmonaut, while the legs with hinge connection attach securely to the outer lining of the craft. The cosmonaut will be able to work with two hands.

The cosmonaut will be able to carry out certain work in orbit without going into open space, but by using small hermetically sealed capsules which will be sent into orbit on board the spacecraft (or orbital station). In these capsules man will be able to work without a spacesuit which inhibits the movement of the cosmonaut. For convenience of work and to provide safety the capsule can be fastened to the servicable object by strong but easily opened and closed clamps. The capsule that has six degrees of freedom will have to be equipped with motor units to control its movement and stabilization. The cosmonaut in the capsule and involved in the assembly of the station in orbit will have to have certain motor habits to preserve orientation in space and possess visual-motor coordination to control his body and the capsule in space.

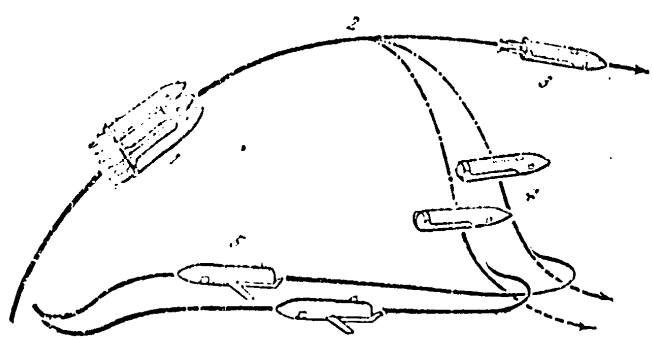
Special flying assembly apparatus will also be created, something like space towing cranes controlled by man. Such apparatus will preferably have a hermetically sealed cabin for two people, autonomous motor unit for maneuvering in orbit, and different apparatus for control and communication, including a calculator. To fulfill the assembly work it will have mechanical arms--manipulators which can carry out all possible operations. The manipulator arms will be manufactured from metal pipes, in whose joint small electric motors will be installed that put them into motion. On the outer walls of the housing of the astrotug in special clamps industrial holders and fasteners will be suspended, as well as tools necessary for the assembly that are subsequently removed in the process of work by mechanical arms.

The power unit of the astrotug can consist of liquid-propellant jet engines fastened on hinges. On board the astrotug in addition there will be a small power unit to supply the control apparatus and the life support system of the crew.

It is assumed that the astrotug will be completely assembled on Earth and not require any finishing in space. After the completion of its main task it can be used to correct the orbit of the station and for its external repair.

The orbital stations will be connected to Earth by transport ships rated for multiple use, a so-called space shuttle. Ideally the shuttle must fulfill a flight from Earth in the same way as an ordinary airplane, pick up altitude up to the assigned orbit, deliver to the point of destination its cargo, again enter the atmosphere, land on an ordinary airport runway, and be ready for the next flight after servicing and filling. Such a transport machine that services the segment "earth-orbit" is still unreal for today's state of science and technology, but the intermediate designs approaching it which could be created by the end of the 1970's already exist in drawings.

The scheme of flight and layout of such a transport craft are shown in the figure (p 68). The craft consists of three rocket blocks: two blocks of the first stage are located along the sides of the block of the second stage. The motor units of all three stages are engaged simultaneously, whereby the motor unit in the block of the second stage until separation of the blocks of the first stage uses the fuel released from them. The separated blocks of the first stage, by using movable wings and turbofan engines return to the launching region. After the fulfillment of the flight task the block of the second stage descends from orbit and returns to .arth to the launching region by using movable wings and turbofan engines.



Flight Pattern of Transport Craft

Key:
1. End of section of vertical lift
2. Separation of units of first stage
3. Exit of units of second stage into orbit
4. Entrance of units of first stage into dense layers of atmosphere
5. Return of units. of first stage to launching region

However no matter how colossal the progress that has been attained in the technology of spacecrafts the transport flights earth-space-earth will remain uneconomical until we learn to use the natural resources of the solar system. Now we have to carry on spacecrafts resources for movement not only on the path from Earth, but also for return. It is little to say that this doubles the difficulties of flight--this at least quadruples them.

In space we can find geological formations and media in the same broad diversity as on Earth. The direct development of the lunar and planetary virgin soil is beginning before our eyes. We already know that on the moon there are valleys and elevations, canyons less conspicuous to the eye, deep troughs in craters, almost vertical slopes, winding valleys similar to the channels of dried up rivers, low domes which could be the roofs of enormous "bubbles" blown up in incandescent rock, and enormous carpets of formerly liquid material (possibly lava).

On the moon at first temporary, and then permanent lunar habitable bases will be set up.

For the lunar settlers primarily it is necessary to create fairly comfortable residences. For this purpose it is advantageous to use artificial or natural deepenings in the lunar mountain massives which will protect the residents from meteorites and radiation danger. It is not excluded that on the moon man will find caves and "tubes" similar to those that on Earth are formed not far from volcanoes by rivers of molten rock. But on the moon the force of gravity is lower, therefore such "tubes" can prove larger than on Earth. Of course such residences must be hermetically sealed, and equipped with lock gate devices for exit into the external airless space.

Many scientists consider that on the moon initially dwellings and auxiliary buildings will be constructed of inflatable hardening plastic that will be inflated with oxygen transported from Earth. Then it is proposed that this oxygen will be continuously generated with the help of chemical treatment systems. It is also possible that for this purpose plants will be used, since they precisely produce the oxygen that we breathe on Earth. On the lunar base they could regenerate the atmosphere, absorbing the carbon dioxide exhaled by people and releasing oxygen.

It will become necessary to obtain oxygen at the site, and not only oxygen, but also as many as possible other constantly expended substances and materials.

Of course the best source of oxygen would be water consisting of 90% of this element. But if there is no water in a pure form, then for this purpose soil and rocks can be used which are rich in crystallized water. This water can be "evaporated" in a solar collector at temperature 3,000°C. Such temperature will be created by solar rays concentrated by a system of lenses and mirrors.

If there is calcium carbonate on the moon, then by having it in a solar collector one can obtain oxygen, carbon and carbon monoxide. It is true that this requires a temperature about 4,000°C. The calculations show that with an area of the collector of 0.84 m^2 265 l of oxygen per hour will be successfully obtained, which will provide life for 15 people.

Metals and silicon, most likely, will have to be extracted from oxides--there are many chances of finding rich ore deposits on the moon.

Oxygen, water, food products, fuel and supplies of electricity in storage batteries probably will be accumulated during the lunar day in such quantities that are required for the lengthy lunar night--a period of inactivity of solar units.

Unique problems are associated with the creation of lunar transportation that is capable of acting reliably in the severe lunar situation, and in a medium of light gravity. Even now there is no shortage of plans for different lunar all-purpose vehicles.

As is known during the development the most diverse types of propellers were analyzed: caterpillar , walking, and even jumping. However the wheel was acknowledged as the most optimal. High reliability combined in it with economy and simplicity of design.

The considerable length of the wheel system makes it possible for the machine to overcome wide cracks and projections. With this type of propeller the rubbing parts can be reliably protected from the effect of space vacuum and penetration of lunar dust. The wheels that have individual drive make it possible to continue movement even when some of them malfunction.

A lunar vehicle on a gas blanket is also proposed for moving the cosmonauts over the lunar surface. According to calculations under conditions of lunar gravity and vacuum to provide movement of the lunar vehicle gas pressure of 3.5×10^{-4} kg/cm^2 will be sufficient. The lunar vehicle is rated for two cosmonauts. The control mechanisms, gas supply and main motor of the apparatus are mounted on a central platform.

In the opinion of a number of scientists the lunar vehicles on a gas blanket will guarantee greater velocity of movement and higher capacity for cross-country travel than wheels. They will be able to develop speed up to 50 km/h, overcome craters up to 3 m in diameter and rocks up to 0.6 m in diameter.

The caterpillar lunar all-purpose vehicle with rocket system--is yet another variant of the lunar all-purpose vehicle. Equipped with three stable caterpillar supports and rockets it can creep over the lunar surface and make short flights above it. Such an all-purpose vehicle has very high maneuverability. It can be turned practically on the spot and can be moved from that spot in any direction.

This variant of all-purpose vehicle is rated for lengthy autonomous expeditions with a multiple crew. It can cover distances of hundreds of kilometers. Its energy sources--fuel components, storage batteries and radio-isotope thermoelectric generators.

With time the moon will be covered by a network of hermetically sealed lunar residences and enterprises. In the numerous lunar laboratories experiments will be carried out and astrophysical studies that are impossible on Earth. Based on the lunar minerals unique industrial complexes will be built. Human activity on the moon will be associated with an enormous number of new projects and completely unusual solutions in the field of construction.

Due to the intensive development of the moon the problem arises of a large number of transport flights in order to supply to the lunar surface scientists, engineers and service personnel. It is considered that the most effective means of communication between the Earth and moon can prove to be the aerospace airplane.

Its take-off will be horizontal as in the modern airplanes. The ramjet-rocket engines and devices for air liquefaction will guarantee acceleration up to hypersonic velocities. The passenger compartment will be separated from the booster airplane with G-force slightly over 1.5 g during the flight along a ballistic trajectory beyond the limits of the atmosphere, after which the airplane will begin descent to land on the aerospace field, while the passenger compartment will be put onto the final trajectory for flight to the moon by the jet engine that gives it the necessary velocity.

The engines of the craft will operate almost continuously during the entire flight, otherwise it would be necessary to give it a rotating movement to create an artificial gravity force. On the greatest segment of the trajectory the lunar craft will be accelerated, then it will be turned by 180° for deceleration and transfer to the orbit of a lunar satellite.

Even with very advanced jet engine units the lunar spacecraft will not be able to land on the lunar surface without additional stages of single action. Therefore instead of landing the craft on the moon one can provide for its meeting with a space station located at the libration point, where the passengers are transferred to a special landing apparatus.

In the development of planets, judging from everything, the same sequence will be preserved as for the moon: first exploratory automatic probes will be sent to the environs, then a soft landing on the surface of the planet by automatic stations, finally the first expeditions that mark the beginning of the settlement of the planet and the use of its resources.

Studies of Venus and Mars are of great importance in the first place for understanding the origin and evolution of the solar system in general, and of Earth in particular. A study of Mars is important also from the viewpoint of biology. On the example of the American program "Viking" a shift is clearly visible in the center of gravity of the scientific research towards complex experiments including both a broad circle of tests to investigate the organic chemistry of the Martian surface, as well as carrying out purely biological experiments.

Whereas one of the planets on which the scientists placed great hopes until recently was Venus, now Mars has occupied the first place. The conditions on Venus strongly limit its studies even with the help of unmanned apparatus. It is evident that it will be more difficult for man to create conditions for landing on this planet in the near future. Mars is a more hospitable planet.

The problem of man's flight to other planets consists, however, not so much in the complexity of conditions on these celestial bodies, as in the distance to them. Thus, for example, Mars in the periods of opposition (once in 2 years) is located 56 million km from Earth, i.e., almost 150 times farther from us than the moon. A number of other problems are associated with distance. In order to travel to Mars with return to Earth man has to negotiate hundreds of millions of kilometers in space, and this will take about 3 years. None of the modern spacecraft are capable of carrying on board such a quantity of supplies of oxygen and food in order to guarantee for this period the living conditions even of a small crew. For expeditions of 10 people it would be necessary to have supplies of water, oxygen and food products weighing about 70 T. And this is without consideration for a possible delay. Therefore a flight to Mars would require not an ordinary craft, but an earth in minature. The scientists call a "closed-cycle system," where use of wastes would be set up in order to continually restore the atmosphere to reproduce the food products on board.

All human vital activity in outer space would have to occur in a continuous single cycle, i.e., in such a way that everything that is released is absorbed, and everything that is absorbed is restored, so that it can be used again. Discharges of the organism can be used to grow plants which are used by man and animals for food; in addition the plants, absorbing carbon dioxide and solar energy will supply oxygen necessary for the organism.

In order for the turnover of substances to be stable the system must include producer organisms that create organic substances; consumer organisms that are fed by the producer organisms; destroyer organisms that break down the organic compounds of the wastes of vital activity of organisms of the first two types to an inorganic substance; finally inorganic components of the system forming a medium in which these organisms live. As an energy source in such a system, as in the turnover of substances on Earth, there will be the sun.

For man's flight to Venus or Mars an engine is not suitable that operates on ordinary chemical fuel, since the duration of the voyage proves to be extremely great. For this purpose more powerful energy sources are needed, more precisely, sources with a high degree of energy concentration in a unit of mass.

Nuclear energy contained in an atom is a million times greater than chemical energy. Therefore it is most probable that nuclear energy will be used for the interplanetary flights. One of the most suitable at the first stage will apparently be the solid-phase nuclear rocket engine. The "heart" of the reactor in such an engine will be a vertical cylindrical core consisting of a solid matrix made of refractory material, within which vertical rods of the fissionable material are placed in regular order, contained in a pipe made of heatproof material. Around the core of decay there is a reflector consisting mainly of the same material as the core of decay, i.e., of elements or group of elements of low atomic weight, such as hydrogen, deuterium, beryllium or carbon in the form of graphite. Between the rods of the atomic fuel control rods made of boron compounds are placed in a regular order. Pure uranium-235 can be used as the fissionable substance, but most likely uranium carbide or uranium dioxide will be used that have a lower working temperature.

The interplanetary craft will have an enormous weight. Therefore its assembly should be carried out in orbit from individual completely prepared blocks. Initially the actual craft (without cosmonauts) will be put into a base geocentric orbit. Then rocket blocks with nuclear engines will be put into the same orbit--booster rockets to transfer the craft from a geocentric orbit to trajectory for flight to Mars, and sustainers to transfer the craft from a trajectory for flight to Mars to an areocentric orbit for subsequent transfer from this orbit to trajectory for flight to earth, and finally for transfer from this trajectory to a geocentric orbit.

All the rocket blocks will be put into orbit completely prepared with the working body, but it will be possible to replenish them with the help of a transport apparatus of multiple use. The same transport apparatus will supply cosmonauts and the necessary resources to the Martian craft.

The manned landing module of the Martian craft will consist of a landing and a flight stage. During the flight to Mars the landing module with the help of the on-board engine will descend from an areocentric orbit and enter the atmosphere of Mars by using aerodynamic deceleration. When the velocity of the module is reduced to the local velocity of sound, a thermal-protection screen of the deceleration engine unit will be discharged and the compartment will land with the help of this unit and a parachute system.

The task of the first cosmonauts landing on the Martian surface will include magnetic, gravitational, and seismic studies, collection of soil samples, obtaining of atmospheric samples, search for life, study of the behavior of life forms under Martian conditions, and search for water and other natural materials on the planet. For movement of the cosmonauts the landing module will be equipped with a self-propelled vehicle.

After the fulfillment of the program of research the cosmonaut in the launching stage of the landing module will blast off from Mars. After return of the expedition to the craft and transfer of the cosmonauts to the orbital module the launching stages of the landing modules will be released.

The route of the flight "Mars-Earth" will pass near Venus. This will make it possible during the flight near this planet to study it with the help of an unmanned apparatus.

The crews of the Martian craft will be sent to Earth evidently by transport crafts of multiple use. In principle the Martian craft, besides the orbital module and the manned landing module can include also a module for descent to earth. The increase in the weight of the craft in this case will be slight.

It is also evident that it will also be expedient to provide in the construction of the craft an unmanned apparatus which could land on the surface of Mars and then return to the craft with samples of Martian soil and results of studies. After an evaluation of the data obtained from the unmanned landing apparatus a decision could be made on the landing of the expedition.

Of considerable importance in the investigation of the outskirts of the solar system and the giant planets--Jupiter and Saturn. Specification of their composition--the correlation between highly volatile, silicate and iron components--is of basic importance for an understanding of the differentiation of a protoplanetary cloud at different distances from the sun and conditions of substance condition of the planets. The increased brightness of Jupiter in the radio range forces us to assume there is increased heat emission by the giant planets which could conceal the rudiments of stellar energy, and are a type of "stars that have not taken place." Therefore it is understandable why the specialists are interested in flights to Jupiter by automatic interplanetary stations. One can hope that as a result of such flights important scientific results will be obtained.

Quite recently practically all the scientists rejected the possibility of existence of life on upiter as a consequence of the "toxic" atmosphere of this planet. Today, however, the narrowness of such a view is beginning to be recognized. Modern space theories assume that about 4 billion years ago the earth was enveloped in gas similar to that which now surrounds Jupiter. But precisely under such conditions primitive life on Earth was born! Only at a later stage, when plants emerged were compounds containing hydrogen in the atmosphere such as methane and ammonia gas squeezed out by oxygen. And only after this did the animal world appear.

Thus, one can assume that Jupiter is at the starting stage of biological development. This can also explain the unusual coloring of its atmosphere, typical for many complex organic compounds.

Due to the astronomical instruments sent into a near-earth orbit we will learn very quickly whether this is fantasy or reality. But evidently it will still be a long time before a manned interplanetary craft will be sent to Jupiter with its atmosphere shaken by terrible storms and showers that are incomparable to those on Earth. During this century and a considerable portion of the next man apparently will be able to tread only on the nearest planets of the solar system, Mercury, Venus and Mars. After the implementation of manned flights to Venus, Mars and Mercury the potentialities of the solid-phase nuclear rocket engines will apparently be exhausted. For a lengthy flight in the yet unstudied regions of the solar system more economical engine units will be required.

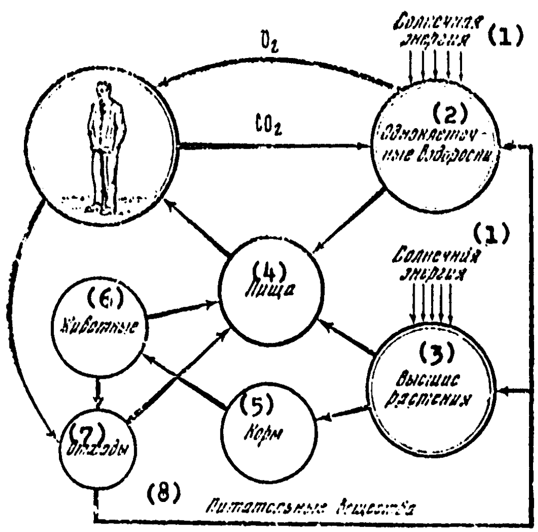
The impulse nuclear jet engines (NJD) and thermonuclear can become such units. The external impulse NJD uses energy from the explosion from a large number of small charges located on board the rocket. These charges successively are released from the rocket and exploded a certain distance from it. With each explosion part of the expanding gaseous fission fragments in the form of plasma with high density and velocity collide with the rocket base--the propelling platform. A quantity of plasma movement is transmitted to it and the platform is advanced with great acceleration. The acceleration is reduced by the damping device to several g in the nosecone of the rocket, which does not exceed the limits of endurance of the human organism.

In the internal impulse NJD the nuclear discharge is exploded in a "combustion chamber" filled with a working body which is heated, and then escapes from the engine, creating thrust. Here all the explosion products in the entire weight of the working body are used to create the thrust.

The reaction of hydrogen conversion into helium will be used in the thermonuclear rocket engine. The design of the thermonuclear engine is simpler. From the viewpoint of cost and economy it also surpasses the impulse NJD.

Both types of engines "impulse and thermonuclear" will provide specific thrust corresponding to the energy requirements of a flight within the solar system with permissible length of the voyages.

If we want to leave the solar system and go to one of the closest stars, then the velocities that can be provided by nuclear and thermonuclear engines will prove insufficient. As is known the closest immobile star, Centaurus is 4.3 light years away from us, i.e., the light dispersed at a velocity of 300,000 km/s will reach us in over 4 years. A simple calculation shows that a spacecraft in order to traverse such a distance even with a velocity of 100 km/s needs over 1,200 years.



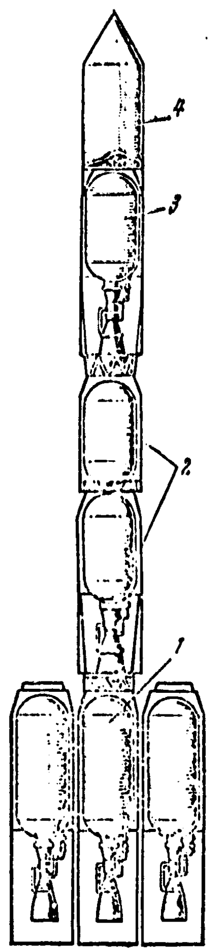
Scheme of Ecological System of Closed Cycle

Key:

1. Solar energy
2. Single-celled algae
3. Higher plants
4. Food
5. Feed
6. Animals
7. Wastes
8. Nutrients

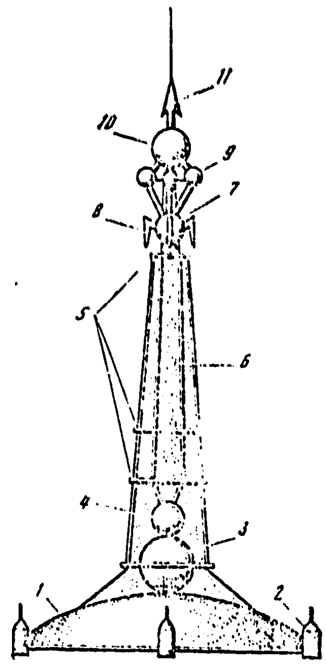
In order to cover interstellar distances velocities are required that are close to the speed of light. The only method of reaching such a speed is to use so-called photon rockets.

In the modern schemes the photon rocket is somewhat like a gigantic projector. It is assumed that one half of the working body will be matter, while the other antimatter which entering into a reaction annihilate, i.e., are converted into electromagnetic radiation. Here the radiation will be given a directed nature, with the help of a screen (mirror) a flow of photons is reflected to the side opposite to the direction of flight. The radiation creates the necessary thrust.



Plan of Controllable Craft for Flight to Mars

Key:
1. Rocket units for transfer from geocentric orbit to trajectory for flight to Mars
2. Rocket units for transfer from trajectory of flight to Mars to areocentric orbit
3. Rocket units for transfer from areocentric orbit to trajectory for flight to Earth
4. Martian craft



Scheme of Interstellar Photon Rocket

Key:

1. Reflecting "dish" (mirror)
2. Master engines
3. Tanks with antimatter
4. Tanks with matter
5. Shielding screens
6. Main compartment
7. Living areas of cosmonauts
8. Emitters
9. Spherical observatories
10. Central control post
11. Space rocket glider

A flight to the nearest stars will take years or decades. But will it be possible to reach stars whose light reaches the earth in hundreds or even thousands of years? It seems that only a negative answer is possible to this question since the travel time would exceed the average duration of human life. Two solutions to this problem are theoretically possible.

First--one generation of people is established on board an interstellar spacecraft, and within several generations their progeny will reach the distance worlds. The second--to create metabolic preparations which will be capable in a significant way of delaying the biological activity of the organism of the crew members, so that their lives will last several centuries.

There exists yet another problem. According to Einstein's theory of relativity the rhythm of time on an object moving with great velocity is reduced. And the reduction will be especially perceptible when the velocity approaches the speed of light. A flight to a neighboring galaxy, Andromeda, on a photon rocket in time measured on board a spacecraft could be completed in 9 years. On earth about 750,000 years would have passed. This period is so great that during such a time the surface of the earth and its climate could be changed so much as to be unrecognizable.

Although the practical realization of photon rockets and interstellar crafts in general evidently will encounter exceptional difficulties truly unlimited possibilities for spreading into space are unfolding before mankind. Theoretically it is capable of penetrating as far as it wants into the universe surrounding us. It is also probable that other, nonrocket methods of movement into interstellar space will be found. For example, gravitational waves, the effect of electrical and magnetic fields in the interstellar space will be successfully used.

However all of this is still too far ahead.

The nearest plans for interplanetary voyages are so enticing and attractive that they force the scientists to concentrate attention on them as the primary tasks of astronautics.

The prophetic words of the founder of rocket technology, astronautics and the theory of interplanetary communication Konstantin Eduardovich Tsiolkovskiy are beginning to come true: "Mankind will not remain forever on Earth, but in the pursuit for light and space will timidly penetrate beyond the limits of the atmosphere, and then conquer the entire near-solar space."

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GEOPHYSICS, ASTRONOMY AND SPACE

RADIATION HAZARD FROM SOLAR FLARES IN NEAR-EARTH SPACE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 17, Issue 1, 1979 pp 122-126

[Article by V. M. Petrov, A. V. Kolomenskiy and M. V. Zil']

[Text] 2. Methods of Estimating the Dose and the Risk of Exceeding It

On the basis of a statistical model of radiation conditions caused by solar cosmic rays a method is expounded for estimating the absorbed dose of protons from solar cosmic rays and the probability (risk) of exceeding it in orbital space flight. Estimates of the risk-dose relation are given for various variants of the orbital flight.

A model description of the radiation conditions due to solar cosmic rays was obtained in the paper [1] as a result of an analysis of statistical data. This description is the starting point for the analysis of the dose of solar cosmic radiation and the probability (risk) of exceeding it in space flights of various duration.

The procedure for estimating the dependence of a dose on the chance of it being exceeded is based on application of the Monte-Carlo method. This procedure consists essentially of the following. A great number of flights of a certain type are considered; they are called histories according to usage in calculations by the Monte-Carlo method. In each history random characteristics such as origin times of flares, total proton flow per flare, characteristic hardness of the spectrum, perturbation of the geomagnetic field present during the proton flares, intensity of the perturbation are considered. From the characteristics found for each history the doses in the spacecraft compartments are calculated taking into account the flight trajectory. Then, on the basis of all the doses realized, the relation between the dose and the risk of exceeding it is constructed for the flight variant under consideration.

The moments of origin of proton flares are determined by direct modelling, and the time interval between two consecutive flares is calculated according to the formula

$$t_k - t_{k-1} = \ln \underline{a}/\lambda, \qquad (1)$$

where t_k is the moment of origin of the kth consecutive flare, $\underline{a}$ is a random number distributed uniformly over the interval from 0 to 1, λ--the frequency of flares. If $t_k \geqslant T$, where T is the flight duration, the history is terminated.

The remaining random characteristics of the radiation environment--proton flow, spectrum, magnetic storm intensity--are calculated in the process of modelling from expressions of the form

$$\int_{Y}^{Y_{max}} f(Y)\,dY = a, \qquad (2)$$

where $\underline{a}$ is, as before, a random number, Y--the magnitude of the random characteristics, Y_{max}--the upper limit of variation of the random characteristic, f(Y)--the distribution density.

The event which consists in a flare occurring against the background of a magnetic storm is defined by the coordinate of the random $\underline{a}$ falling into the segment 0...1. If $\underline{a} \leqslant \underline{a}_0$, the flare occurs against the magnetic storm background; otherwise there is no perturbation.

In this case $\underline{a}_0 = 0.34$ is the frequency of observation of flares against the background of magnetic storms.

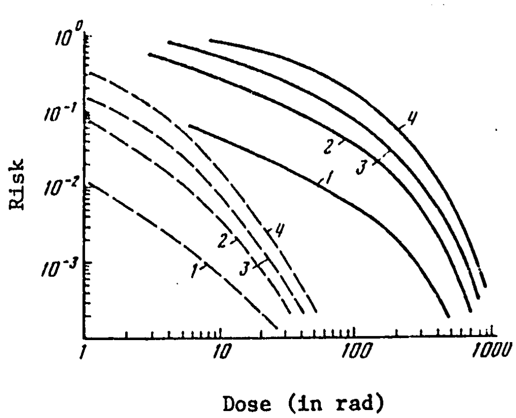


Fig. 1. Risk of exceeding a dose as a function of the dose for orbital flights: the orbital inclination is 51° (dashed lines) and 71° (solid lines). The numbers 1, 2, 3, 4 correspond to flight duration of 14, 91, 182, 364 days. Thickness of the aluminum shield 1 gm/cm^2.

The characteristics obtained in this way were used to calculate the dose behind the shield from each flare in orbital flight:

$$D_\kappa(\delta, R_0, \Phi_0, X) = l \int_{t_K}^{t_K + t_{fl}} \int_{E_{co}(t,X)}^{\infty} f(t, E) C(E, \delta)\, dt\, dE, \qquad (3)$$

where t_K is the initial moment of increase of the proton intensity, t_{fl}--the duration of the flare, $f(t,E)$--the dependence of the proton intensity on time and energy, $E_{co}(t,X)$--the cut-off energy as a function of the current coordinates of the craft and of the intensity of geomagnetic field perturbation X, $C(E,\delta)$--the conversion factor from the flux to the dose behind the shield of thickness δ; ℓ--coefficient of shielding of the flux by the earth.

It was assumed in the calculations that the characteristic spectrum hardness R_0 does not change during a flare and that the time dependence of the intensity for proton energies above 30 MeV is of the form [2]

$$f(t, E) = At\, e^{\alpha t} e^{-R(E)/R_0},$$

where

$$\alpha = \frac{1}{t_\kappa}, \quad A = \Phi_0 \Big/ \left\{ t_n^2 \left[1 - \left(2 - \frac{t_c}{t_n} \right) \right] \exp\left(\frac{t_n + t_c}{t_n} \right) \right\},$$

Φ_0 is the integral flow of protons with the energy 30 MeV per flare, t_n--the rise time of the intensity, t_c--the decay time, $R = \sqrt{E^2 + 1876E}$--the hardness-energy relation for the proton.

The cut-off hardness at each point of the spacecraft trajectory in the absence of geomagnetic perturbations was determined by interpolation of table values from the work of Quenby and Wenk [3], and the trajectory coordinates from the formulas for the motion of artificial earth satellites [4]. It was assumed that for northern and southern geomagnetic latitudes above 70° there is no cut-off.

The relation between the intensity of geomagnetic perturbations and the cut-off hardness was obtained from Solomon's formula [5]:

$$P(x) = P_0 \left\{ 1 + \frac{xr^3}{M} (4 \cos^{-6} \varphi - 1) \right\}, \qquad (4)$$

where M is the earth's magnetic moment, P_0--the cut-off hardness for unperturbed magnetic field, φ--the geomagnetic latitude, r--the distance from the center of the earth.

In accordance with the given procedure an algorithm has been worked out and a program has been set up in Fortran for the YES-1030 computer, which makes it possible to calculate the relation between the tissue dose and the risk of exceeding it for various variants of orbital flight.

In the present work calculations have been made for flights on circular orbits at 300 km and for 14, 91, 182, and 364 days. Flight variants have been considered with orbital inclinations of 51°, 65°, 71°, 90° and with aluminum shielding ranging in thickness between 1 and 10 gm/cm^2.

At least 10^4 histories were investigated for each variant. With the risk value of 0.01 the statistical error did not exceed 10-12%. The rise time of the proton intensity was assumed to be equal to 9 hours for all flares and the decay time to 27 hours. These amounts conform to statistical data taken from [2]. The earth's shielding coefficient was assumed equal to 0.5.

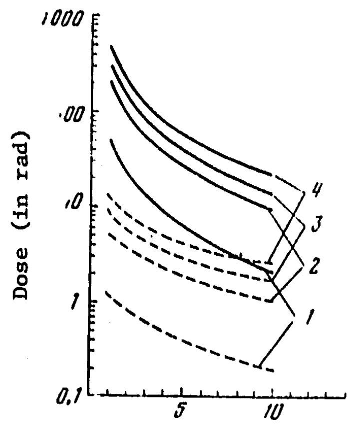
As a characteristic of the radiation environment within the compartments the local dose (dose of a tissue-equivalent point dosimeter) is taken. Its use yields the upper estimate of the absorbed dose for objects of finite dimensions (in particular for the model of man).

We will examine the influence of various orbital flight parameters on the risk-dose relation. Fig. 1 presents the dependence of the risk on the dose for flights on orbits inclined 51°. It is evident that the irradiation risk grows as the orbital inclination and the flight duration increases. Thus, for instance, the irradiation risk for a dose of 30 rad in year-long flights on orbits inclined 51° and 71° behind 1 gm/cm^2 shield is 0.001 and 0.5 respectively.

With fixed values for the risk the irradiation dose also increases as the orbital inclination and the flight duration increase. Fig. 2 presents the dependence of the isorisk dose on the thickness of the aluminous shield for inclinations of 51° and 71°. The irradiation risk is assumed equal to 0.01. This amount of risk may be considered acceptable for estimates of the radiation hazard in space flights [6].

It is evident from Fig. 2 that, with the same shield thickness and flight duration, the dose is considerably smaller for the 51° inclination than for 71°, which is explained by the effect of shielding of the particle flow by the earth's magnetic field. In the first case, with a shield thickness of 1 gm/cm^2 and flight duration of 1 hour, the dose is 12 rad. This amount does not represent a serious danger for a human being.

In the second case the dose may be $\sim$400 rad under analogous conditions. In this case to lower the irradiation dose to the level of 50 rad, for example, a shield thickness of 5 gm/cm^2 is required. An analysis of the results presented in Fig. 2 shows that with a risk of 0.01 and a fixed shield thickness the dose increases with increasing flight duration according to the law $\sim \sqrt{T}$, which is in agreement with the results of calculations for flight in free outer space [7]. It is interesting to compare the scale of doses and risks in orbital flights and in flights in free outer space.



Shield thickness (in gm/cm^2)

Fig. 2. Dependence of the isorisk dose on the thickness of aluminum shield for flights inclined 51° (dashed lines) and 71° (solid lines). The numbers 1, 2, 3, 4 correspond to flight durations of 14, 91, 182, 364 days (risk--0.01).

Fig. 3 presents the risk-dose curve for orbital flights (solid curves) and flights in free outer space (dotted curves) of 1 year duration.

The same figure shows, for comparison, the results obtained in papers [7, 8],--corresponding to curves 6 and 7 respectively. The data of [7, 8] have been converted by us from fluxes to doses. It was assumed that in free space the proton spectrum (R_0 = 80 MeV) is realized.

In comparing the curves for orbital flight and for flight in free space (curves 1-4 and 5) it is evident that for the same risks the doses in orbital flight are considerably lower than in free-space flights.

Thus, for a risk of 0.01 the dose in an orbital flight with 90° inclination the dose is 28 rad, while in free space it is $\sim$160 rad. This fact is explained to a considerable extent by the shielding effect of the geometrical field and of the earth itself.

The substantial differences in the curves 5-7 are explained by different approaches in taking into account the most powerful flares.

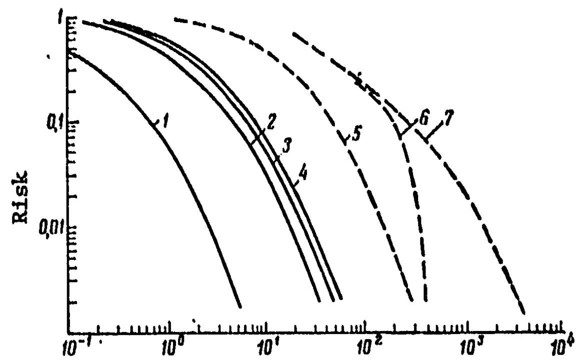


Fig. 3. Risk of excess dose for orbital flights (solid lines) and flights in free outer space (dashed lines) of 364 days duration. Shield thickness 10 gm/cm^2; 1, 2, 3, 4--curves for flights in orbits inclined 51°, 65°, 71°, 90° respectively; 5--curve for flights in free space; 6, 7--curves for flights in free space according to the papers [6, 8]

In paper [7] it was assumed that the maximum proton flux is limited to the quantity 1.2×10^{10} protons/cm^2 (upper limit of expression (2)). In paper [8] the maximum flux was practically unlimited. In the present work we have limited the maximum flow to the quantity 8×10^9 protons/cm^2. This amount was observed in the flare of 8-3-1972.

Conclusions

1. A procedure is proposed for estimating the relation between a dose and the risk of exceeding it for protons of solar cosmic rays in near-earth space.

2. The procedure indicated may be utilized for estimation of the radiation hazard in orbital space flights.

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PUBLICATIONS

ENGINEERING, PSYCHOLOGICAL PLANNING OF AUTOMATIC CONTROL SYSTEMS

Moscow OSNOVY INZHENERNO-PSIKHOLOGICHESKOGO PROYEKTIROVANIYA ASU TP (Foundations of Engineering and Psychological Planning of Automatic Control Systems for Technological Processes) in Russian 1978 signed to press 15 Jun 78 pp 4-9, 204-208

[Annotation, foreword, introduction, bibliography, and table of contents from book by A. I. Galaktionov, V. A. Trapeznikov, A. A. Voronov, A. G. Mamikonov, O. I. Aven, and D. M. Berkovich, Energiya, 11,000 copies, 208 pages]

[Text] In the book are presented the theoretical bases of planning automatic control systems for technological processes as a man-machine control system. Analysis is performed on specifications, primary problems, and approaches of engineering and psychological planning. Study results of the structure of mental activity of the technologist-operator are presented: approximate models of his activity are constructed which make it possible to solve the primary problems of construction of man-machine systems. Methods, means of study, and evaluations of man-machine systems are described with the aid of universal simulating complexes. Promising methods and means of data display are described.

Intended for planning engineers, operators, psychological engineers, experts in scientific organization of labor, as well as students, graduates and instructors of the corresponding specializations.

Foreword

By decision of the 25th CPSU Congress all sectors of the national economy are faced with great and complex tasks to improve the process of control of production and raise its quality and efficiency. Automatic control systems based on modern scientific achievements in control theory, economic-mathematics methods, and computer technology are a powerful means of clear enhancement of the level of production control and encompass both the sphere of organizational control and the technological processes of production.

A general pattern in the development of modern automatic control systems (ACS) for technological processes (TP) is not merely an increased volume and complication of automatic control functions, but also the expansion of system scales: the transition from automation of unit control to control of a group of units up to and including a plant, combine, or sector. An harmonic combination of work in designing systems of all classes is observed for all levels of the production hierarchy. For higher classes of TP ACS technological process control problems come closer and closer to organizational production control while supplementing one another. Their comprehensive solution should yield new results in so-called "integrated control systems" (74).

The primary complexity in planning TP ACS today is not associated so much with hardware and software as it is with the so-called ergonomics of the system. Ergonomics, targeted at organization of the optimum human operator interaction with other system components, conceals within itself the virtually untapped reserves of enhanced efficiency and operating reliability of TP ACS and the objects it controls. Criteria of optimums implies the degree of compatibility of the external and internal means of human operator activity, compatibility of external conditions and psychophysiological states of the human body, and so forth.

Only a partial view of ergonomics of TP ACS is examined in the book--psychological engineering planning (PEP).

The book begins with a brief acquaintance with TP ACS and general problems of planning such systems. The material in Chapter 1 can be useful for those psychologist engineers who are not too familiar with TP ACS. In addition, there was another goal in mind--to permit the reader to compare the hitherto utilized traditional methods of technical planning for TP ACS with the evolving methods of systems psychological engineering planning (PEP).

Chapter 1 contains a general discussion of our proposed approach to the elaboration of approximate methods of TP ACS PEP.

Chapter 2 involves the study of internal means of human operator activity. The results of years of research by the author on the structure of mental activity of a technologist operator are cited in particular. The goal of this research is to reveal the resources of construction of a theoretical model which is adequate for the structure of mental activity and permitting solution of PEP problems. It was found that idealized structures of mental activity which operators try to form during the self-teaching process may be adopted as such a model.

Chapter 3 is devoted to an elaboration of methods available to planners for constructing theoretical models of activity on the basis of his available initial data in early stages of systems design. A series of these methods is suggested and specific examples show how they must be used.

The construction of theoretical models makes it possible to solve the first PEP problems.

Chapter 4 contains a description of approximate methods of solution of the primary problems of PEP. An attempt is made, using specific examples, to give the material presented the form of PEP methods.

Chapter 5, written in collaboration with D. I. Ageykin, Ye. K. Krug, doctors of technical sciences and professors, and Yu. S. Legovich, engineer, describes a universal simulating complex developed to study and plan man and machine systems and the research performed in it.

Finally, Chapter 6 contains a description of several promising principles, methods, and means of data display developed by the author or with his direct participation. A prototype panel is described in particular (Tsement-1 ACS).

The authors is deeply grateful to the participants of some research and developments described in the book. In psychological engineering experiments studying the structure of operator activity participated Ye. F. Gorskiy, V. N. Yanushkin, A. D. Sled', and N. A. Bakhareva, engineers. Participants in writing sections 3.3 and 3.4 were V. N. Shcherbakov and Ye. A. Trofimov, graduate students. Work on creation of a universal simulator complex involved, in addition to the authors indicated, B. A. Faleyev, A. V. Morozov, M. A. Putyato, Yu. I. Orlov, leading designers, Ye. F. Gorskiy, N. A. Bakhareva, V. K. KOstin and A. I. D'yachenko, engineers; the latter also participated in writing section 5.3. In the development described in Chapter 6 of the control panel (Tsement-1 ACS) participants included the late Yu. T. Knopov and D. I. Ageykin, authors of the sporadic monitoring system; Ye. F. Gorskiy and N. A. Bakhareva, engineers; and associates of VIASM, TNIISA, and the Sebryakovsk Cement Plant. Professor E. L. Itskovich and engineer V. L. Volkov also gave useful advice on the control panel.

Introduction

Modern control systems for complex technological objects are by nature automated man-machine systems (MMS) designed to solve problems of centralized monitoring and operative control of technological processes.

They contain two links of different nature which are closely associated by unified functional goals: man (team of people) and the control system hardware, including modern computers.

The overall functional efficiency and reliability of automatic control systems for technologica. ..ocesses (TP ACS) and the objects they control is determined not only by the operating efficiency and reliability of each system link, but chiefly by the degree of compatibility of their combined operation. Most of these systems have until now been built using traditional methods of technical planning: planning only the technical portion of the control system. These methods are very well developed and make it possible to build the TP ACS hardware having the desired characteristics.

Clearly insufficient attention has been paid to questions connected with the organization of activity of the human operator and its compatibility with the operation of the systems hardware. Most emergencies, catastrophes, and lost time today occurs because of operator fault, or more precisely, due to the fault of the planner who did not truly know how to organize operator activity and match it with the operation of the control system hardware. This always causes the system and control object to operator under conditions far removed from optimum. Consequently, enterprises bear significant economic losses.

Attention should be paid to the fact that reserves of the component of overall efficiency which is linked with the perfection of technical means of ACS have now been significantly exhausted. This suggests that we should not anticipate any sudden rise in overall efficiency and reliability of the man-machine system via improvement of hardware in TP ACS. In contrast to this, reserves of increased efficiency in the man-machine system (MMS) which can be obtained by organizing effective interaction of the technical system link and the human operator and interaction between individual operators conceal substantial reserves within themselves. Even comparatively small, effective solutions in this area can be much more effective than tremendous technical solutions.

The following may serve as an illustration. If some years ago the ratio of the number of aviation emergencies connected with operator error was 60 percent and with equipment breakdown was 40 percent, the latter data suggest that the relationship had sharply changed in favor of equipment. At this time over 90 percent of emergencies occur because of man. The reason for this is that improvement of technical solutions proceeds more quickly than solutions to questions of the human factor. On one hand this raises technical reliability, while on the other hand it increases the number of variable parameters and consequently, means of data display, complicating the work of the human operator.

Psychological engineering and ergonomic research are now undergoing rapid development to solve the problem of elaboration of a theory and meaningful methods for planning and designing MMS.

B. F. Lomov and V. F. Rubakhin, great Soviet experts in engineering psychology, noted in (60) that the primary content of engineering psychology is the study and planning of operator activity with subsequent optimization of informational interaction of man and equipment in ergatic systems. In the future it is necessary to construct a theory of planning and open up the controlling principles forming the basis of informational interaction.

A considerable number of studies have been devoted to particular planning issues of MMS (43, 55, 57, 58, 61, 63, 64, 73, 80), and some to general methodological issues concerning the structure, tasks and principles of PEP. These studies are mentioned at the appropriate points in this book.

Elaboration of a PEP theory requires close interaction of various contiguous scientific fields involved in the construction of control systems and the study of human activity. General systems theory, cybernetics, operations research theory, systems engineering, computer technology, mathematics, general psychology, ergonomics, phsyiology, pedagogy, sociology, scientific organization of labor, technical esthetics--this is an incomplete list of the scientific theories from which engineering psychology should dig out information to solve its own primary problem.

The importance and urgency of work aimed at elaborating a special theory of MMS design have been noted in studied many times by Academicians A. I. Berg (8), V. A. Trapeznikov (81, 82), and B. N. Petrov (67, 68). They proved that this problem is a new step in the evolution of a general theory of control and is a vital national economic problem.

The goal of this book is the author's atttempt at finding an approach to approximate methods of TP ACS PEP. The modern planner who knows methods of traditional technical planning has not only recognized the need to use the systems approach, but has also tried to apply them in his projects. But the lack of accessible methods of solution retards the penetration of systems PEP into practice. Some proposed approaches of engineering psychological analysis, synthesis and evaluation based on construction of mathematical models of activity frighten planners with the complexity of the PEP problem solving procedure, the difficulty of analyzing initial data on the characteristics of activity of the human operator under various conditions of work, and data on characteristics of information flows. Planners can not understand the abstract mathematical models of activity of the human operator suggested by some authors. The first attempts at using such models required significant expenditures of labor and time, and the reliability of the results was very low.

Approximate methods of PEP described in this book are free of the shortcomings of the aforementioned approaches to MMS design. Their initial data are the data familiar to the modern planner, obtained in early stages of planning. In the first stage of development of the proposed methods, characteristics of activity of man and information flows were not utilized. When possible qualitative methods of evaluation of synthesized versions of PEP problem solving are used: experimental testing is suggested for their verification.

The structure of mental activity is given in the form of clear, directional, acyclical graphs.

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PUBLICATIONS

UDC 621.396.6:621.318.3

ELECTROMAGNETIC DEVICES IN RADIOELECTRONIC APPARATUS

Moscow ELEKTROMAGNITNYYE USTROYSTVA RADIOELEKTRONNOY APPARATURY in Russian 1978 signed to press 20 Dec 77 pp 2, 167

[Annotation and table of contents from book by Leonid Alekseyevich Kazakov, Izdatel'stvo Sovetskoye Radio, 21,000 copies, 168 pages]

[Text] Under consideration here is a large class of electromagnetic devices used in radioelectronic apparatus and automation equipment: electromagnetic drives and mechanisms, steppers, switches, brakes, clamps, locks and others as well as their actuator elements (electromagnets, electromagnetic clutches). Their functions, structural features, advantages and basic parameters are noted, and the design procedure is outlined. Typal configurations of actuator elements are shown and electromagnetic as well as structural parameters of the latter given. Outlined are also the basic principles of rational design and engineering methods of calculation.

This is essentially a handbook, copiously illustrated and containing information sought by many developers of radioelectronic apparatus and automation equipment, which should also be useful to students at higher educational institutions where instrument design and electrical engineering specialty subjects are taught.

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PUBLICATIONS

UDC 539.216.22:546.28

POLYCRYSTALLINE SEMICONDUCTOR FILMS IN MICROELECTRONICS

Minsk POLIKRISTALLICHESKIYE PLENKI POLUPROVODNIKOV V MIKROELEKTRONIKE in Russian 1978 signed to press 11 Aug 78 pp 2, 341-343

[Annotation and table of contents from book by Vladimir Mikhaylovich Koleshko and Aleksandr Adamovich Kovalevskiy, Izdatel'stvo "Nauka i Tekhnika," 2,600 copies, 344 pages]

[Text] This is the first, and so far, the only survey of practical and theoretical achievements made with polycrystalline films of silicon, germanium, tellurium, selenium and $A^{III}B^{V}$ compounds, their preparation and application in microelectronics for semiconductor integrated microcircuits.

Data are presented on the preparation of polycrystalline films of semiconductor materials, their buildup kinetics and structure as well as physical and chemical properties.

Physical methods of stimulating the buildup of thin films are considered, namely with an electric field, laser radiation, electron bombardment, ultraviolet or microwave radiation and ultra- or supersonic elastic vibrations.

While the book is intended for scientists and engineers working in the electronic industry, it can also be of use to graduate and undergraduate students concerned with problems of thin-film physics or radio- and microelectronics.

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PUBLICATIONS

COMPUTER METHODS AND PROGRAMMING (NUMERICAL METHODS IN PROBLEMS OF ELECTRODYNAMICS)

Moscow VYCHISLITEL'NYYE METODY I PROGRAMMIROVANIYE: CHISLENNYYE METODY V ZADAZHAKH ELEKTRODINAMIKI in Russian Vol 28, 1978 signed to press 30 Jun 78 pp 2, 263-264

[Annotation and table of contents from collecting of works of the Moscow University Computer Center, edited by V.I. Dmitriyev and A.S. Il'inskiy, Izdatel'stvo Moskovskogo Universiteta, 2,140 copies, 264 pages]

[Text] The book, a collection of articles, deals with the application of numerical methods to problems of electrodynamics and is, in terms of the subject matter, a continuation of earlier volumes (5, 10, 13, 16, 20, 24). The first chapter covers new research in diffraction, the second chapter touches on numerical methods in the theory of antennas, the third chapter contains material on research in plasma physics, and the fourth chapter presents results of electrodynamic calculations in geophysics.

The issue is intended for a wide range of specialists in radiophysics, geophysics and plasma physics.

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PUBLICATIONS

MAGNETIC HYDRODYNAMICS

Moscow ZNANIYE, MAGNITNAYA GIDRODINAMIKA, SERIYA FIZIKA in Russian No 2, Feb 79 pp 2-4, 64

[Annotation, table of contents and introduction from the book by Candidate in the Engineering Sciences, Yu.A. Birzvalk]

[Text] This brochure is devoted to an important field of physics: the science of the motion of electrically conducting liquids and gases in a magnetic field, a new area of knowledge which opens up the prospects of creating high power and high efficiency electrical power generators.

The brochure is intended for a wide circle of readers.

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Introduction

Magnetic hydrodynamics, which was founded by the Swedish scientist Alfen, represents a new, rapidly developing field of physics.

It is known from electrodynamics that an electromotive force will appear in a conductor if it moves in a magnetic field, intersecting the lines of force, where this electromotive force leads to the appearance of electrical currents under certain conditions (and practically almost always). In this case, it makes no difference at all what kind of conductor this is: a frame of copper wire, a massive conducting body, a conducting liquid or a gas (plasma) or something else.

On the other hand, it well known that a force acts on a conductor with a current in a magnetic field, which causes the conductor to move if it is not secured. And if the conducting medium is liquid or gaseous, and its particles can move relatively freely, then you cannot pin them down at all. And then the laws of magnetic hydrodynamics begin to be felt.

It seems that everything is simple. In actual fact, the laws governing the motion of the conducting medium in a magnetic field are neither so simple nor so obvious. Many ususpected effects and nontrivial explanations of physical phenomena are encountered. These are discussed in this brochure offered to the readers, which is written by one the leading specialists of the Institute of Physics of the Latvian SSR Academy of Sciences in the field of magnetic hydrodynamics, Yu.A. Birzvalk.

Work was started in this direction at the Institute of Physics more than 20 years ago, and over this time, a large collective of specialists has been brought together, who are working on the problems of magnetic hydrodynamics. Regular, so-called "Riga" all-union conferences are held in Riga on magnetic hydrodynamics; 1978 marked 20 years since the time when the first such conference was held. They always attract the attention of specialists of the entire nation. The all-union scientific and engineering journal, MAGNITNAYA GIDRODINAMIKA, is published in Riga, the only specialized journal on this subject in the world. It is republished in English in the US. Pioneering work started in Riga in a number of directions in magnetic hydrodynamics.

The author of this brochure was awarded the republic prize in 1970 for working out the theoretical principles of conduction MHD pumps. As the executive secretary of the editorial staff of the journal MAGNITNAYA GIDRODINAMIKA, he is always in the mainstream of events, and for this reason, was able to select from the extensive material that which is most characteristic of the development of magnetic hydrodynamics at the present time and in addition, is sufficiently accessible.

I hope that the reader will read through with interest the brochure offered here.

Ya. Liyelpeter, corresponding member of the Latvian SSR Academy of Sciences

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PUBLICATIONS

UDC 539.107.4

WIRE DETECTORS OF ELEMENTARY PARTICLES

Moscow PROVOLOCHNYYE DETEKTORY ELEMENTARNYKH CHASTITS in Russian signed to press 16 Jan 78 pp 2, 167-168

[Annotation and table of contents from the book by Yu.V. Zanevskiy, Atomizdat Publishers, Moscow, 1978, 168 pages, 2,530 copies]

[Text] Wire detectors - spark, proportional and drift chambers - are widely used in experimental high energy physics and comprise the basis of the contemporary electron physics experiment. In recent years, proportional and drift chambers have also been intensively introduced into the related fields of science and engineering: biology, crystallography, medicine, gamma ray astronomy, etc.

The operational principles of wire chambers are presented in the book in systematic fashion, and their parameters are discussed. Electronic recording equipment is analyzed. The areas of application of the chambers in high energy physics and related scientific fields are indicated.

The book is intended for specialists (engineers, physicists and experimenters), engaged in questions of particle detection, for students in the upper level courses and graduate degree condidates, specializing in the fields of biology, biochemistry, crystallography and medicine.

Some 141 figures, 2 tables, and 268 bibliographic citations.

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PUBLICATIONS

MAGNETIC-MEDIUM LOGIC UNITS WITH CONTROLLED MOVEMENT OF DOMAINS

Moscow LOGICHESKIYE USTROYSTVA NA MAGNITNYKH SREDAKH S UPRAVLYAYEMYM DVIZHENIYEM DOMENOV in Russian 1978 signed to press 28 Mar 78 pp 2, 159-160

[Annotation and table of contents from book by M.A. Boyarchenkov, N.P. Vasel'yeva and Yu. D. Rozental', Energiya, 5,000 copies, 160 pages]

[Text] This book examines physical principles and problems of practical realization of logic and switching devices with flat and cylindrical magnetic domains. Principal attention is focused on problems of stability of the domain structure of magnetic media, directional shifting and interaction of domains, recording and reading of information in magnetic media. The authors formulate principal requirements on the parameters of domain-containing materials. They present circuit solutions for various logic and switching devices employing flat and cylindrical magnetic domains. This book is intended for scientific personnel and engineers working in the area of development and utilization of new automatic control and computer hardware devices, as well as undergraduate and graduate students in the corresponding areas of specialization.

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PUBLICATIONS

CONTACTLESS LOGIC CIRCUIT TESTING AND SIMULATION

Moscow STENDOVAYA PROVERKA I MAKETIROVANIYE BESKONTAKTNYKH LOGICHESKIKH SKHEM in Russian 1978 signed to press 9 March 78 pp 2, inside front cover

[Annotation and table of contents from book by I.V. Antik et al., Izdatel'stvo Energiya, 14,000 copies, 80 pages]

[Text] This book contains a survey of methods and means of testing circuits of logic elements.

The authors describe and provide technical data on simulators with series Logika-T logic elements and with series K155 microcircuits. The authors examine methods of bench testing logic circuits, methods of constructing tests and modes of checking them. Recommendations are given on setting up drill and training classes.

This book is intended for designers of industrial process programmed and logical control systems as well as students specializing in the corresponding fields.

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PUBLICATIONS

UDC 621.396.67

NEW BOOK ON ANTENNA ENGINEERING AND TECHNOLOGY

Moscow ANTENNY, SBORNIK STATEY (Antennas, Collection of Articles) in Russian 1978 signed to press 22 Feb 78 pp 2, 201

[Annotation and table of contents from book edited by A. A. Pistol'kors and published by the Scientific and Technical Society of Radio Engineering, Electronics and Communication imeni A. S. Popov, Izdatel'stvo "Svyaz'," 5,800 copies, 201 pages]

[Text] The unique decameter-wave radio telescope UTR-2 at the Academy of Sciences of the Ukrainian SSR is described. The design principles and the characteristics of its antennas are examined, which insure a high directivity as well as the possibility of reception from various directions and at various frequencies with a high degree of noise immunity and easy control. Also described is the decameter-wave radio interferometer URAN-1. Several articles deal with a variety of problems in antenna engineering such as estimating the reliability of phased antenna arrays, reradiation antennas, striplines with ferrite-dielectric fillers, and arrays with switching-type current control.

The collection of articles is intended for scientists engaged in work with antennas.

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